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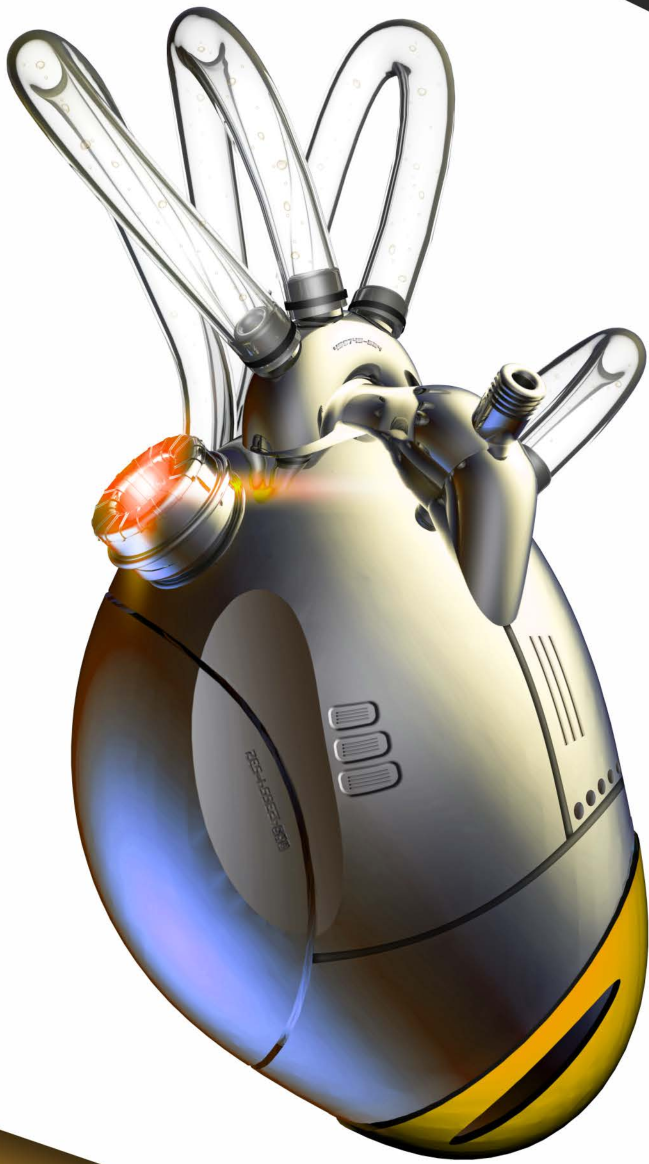

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# Diagnostic Methods and Instrumentation for Aesthetic Skin Conditions

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## Abstract

Aesthetic skin conditions such as dark circles, wrinkles, and pigmentation around the eyes are often the subject of dermatological examination. At this point, an objective and high-accuracy evaluation can be critical in the development of effective approaches. In this study, the proposed instrumentation-based and computer-assisted approaches for effectively characterizing and evaluating skin appearance and health conditions are reviewed. Instruments developed for the assessment of skin features, such as skin elasticity, color change, and pigmentation, including Wood's lamp and spectrophotometer, have been investigated, along with some common computer-aided techniques that complement these methods, such as Wiener estimation, Principal Component Analysis (PCA), pseudo-inverse, and finite-dimensional modeling. The integration of these computational and instrument-based approaches provides a more comprehensive, accurate, and objective assessment of skin conditions and treatment efficacy. The study highlights the continued development of these technologies and their promise to improve dermatological research and practice.

**Keywords:** Dermatology; Instrumentation; Pigmentation; Evaluation; Computational

# 1. Introduction

Dark circles under the eyes, wrinkles, bags beneath the eyes, and other skin imperfections are among the most commonly encountered conditions in routine dermatology. In most cases, determining the prevalence and type of these aesthetically displeasing issues is followed by the application of medications and dermocosmetics. At this juncture, an objective assessment of the treatment's functionality and efficacy is crucial. Effective monitoring of physiological changes largely relies on patient self-assessments, as well as clinical, photographic, and instrumental evaluations. For aesthetic concerns, self-assessments and evaluations based on basic observations can be subjective and prone to error. There are many specialized instrument-based methods for characterizing and scoring cosmetic improvement. Subsequent sections will review some studies that focus on different instrumentation hardware.

# 2. Instrumentation Based Approaches

In one study, the Cutometer (Cutometer®, Courage and Khazaka, Koln, Germany) reference test was used as an objective evaluation method, in addition to a questionnaire. Treatment sessions included the use of a non-ablative fractional laser, bipolar radio frequency, and intense pulsed light. Skin elasticity and the character of wrinkles were evaluated after the series of treatment sessions [1]. The instrument utilized in the study determined the mechanical properties of the epidermis by using a non-invasive, in vivo suction skin elasticity meter [2].

Another technique for measuring color variation is chromametry. The primary purpose of the chromametry device is photographic; however, it also serves as an alternative way to evaluate skin pigmentation [3]. Mac-Mary et al. used the chromametry device to measure and characterize dark circles. Their assessment includes in-situ clinical scoring of the intensity of the dark circles in three zones under the eye by an expert. The study also includes a color analysis of the three zones and the control zone on the cheek using chromametry [4]. In other research, a chromametry device was utilized by Lee et al. for objectively measuring periocular pigmentation in subjects of different ethnicities. They used a Minolta CR-400 Chromameter (Tokyo, Japan) for the quantitative evaluation and analysis of the reflected light [5].

A Wood's lamp, more commonly known as a black light, is an ultraviolet light source that illuminates areas of the skin. The light from this device highlights differences in pigmentation, scars, and skin textures with varying intensities, aiding in the evaluation of diverse skin conditions [6]. In one study, Huang et al. proposed a new scoring approach for dark eye circle assessment, which is based on Wood's lamp and ultrasonogram. They noted that Wood's lamp would be an effective solution to the problem of differentiating between brown and blue/purple hues in mixed types of dark eye circles [7]. Additionally, Goldman et al. performed a Wood's lamp examination to differentiate between epidermal and dermal pigmentation. They

decided on the way of treatment with respect to that classification [8].
One of the instruments that has been widely used to measure skin color is the contact-type spectrophotometer. It is functional for determining melanin and hemoglobin contents. Kikuchi et al. determined the characteristics of dark circles around the eyes to evaluate the effects of applied cosmetics. They used a spectral camera (Hyper Spectrum Camera, HSC1700; Hokkaido Satellite Corporation, Tokyo, Japan), equipped with an array sensor with an eight-bit monochrome CCD camera, and with a spectral range of 350–1050 nm containing 141 bands at 5-nm resolution. Authors reported that they effectively visualized the distribution of melanin concentration and hemoglobin oxygen saturation ratio, which would be directly related to dark circles [9]. In another study, a regular cell phone was used by He and Wang for hyperspectral imaging to monitor hemodynamics and analyze skin morphology. It should be noted that their approach was also computer-aided. They implemented the Wiener estimation algorithm to reconstruct hyperspectral data from RGB images captured by the smartphone camera [10]. Similar to previous studies, Rosen et al. employed a rapid scanning reflectance spectrophotometer to understand immediate pigment darkening in human skin upon exposure to ultraviolet-A and visible radiation, concluding a correlation between increased wavelength and diminished pigment darkening response [11]. In a distinct study, a Wood's lamp test was employed to classify dark circles, with an amalgamation of instruments and computer software, including a chromameter (Chromameter CR-400, Minolta, Tokyo, Japan), to differentiate between dark circle and normal groups [12]. A novel imaging system, SpectraCam®, was unveiled by Nkengne et al. in 2017, identified as a robust hyperspectral imaging system that quantifies melanin, total hemoglobin, and oxygen saturation, proving its suitability for cosmetic research [13].

# 3. Computer Aided Assessment of Cosmetic Variation

Utilizing instruments to evaluate skin conditions provides an objective means of assessment, yet there are many numerical and algorithmic methods available that supply the essential computational processing power for such instruments. Among the techniques that require software solutions, spectral imaging of the skin is prominent. The use of spectrophotometric devices for routine tasks can be both expensive and challenging to secure. A widely preferred algorithmic approach is the adaptation of the Wiener estimation method, which is frequently employed to estimate spectral reflectance from RGB images, captured by color CCD cameras. Nishidate et al. have reported that they have effectively adapted Wiener estimation for generating multi-spectral diffuse reflectance images from a single frame of Red-Green-Blue images acquired with the exposure time of 65 ms (15 fps). Their study is concluding that implemented method is efficient for monitoring chromophore contents in human skin tissue [14]. Also Chen and Liu presented a paper that introduces a modified version of Wiener estimation. They have reported that their approach combines a set of synthetic optical filters with a system matrix obtained from the original RGB values to generate a modified Wiener matrix. They have evaluated their approach with 200 skin sites and concluded that their modification improves the estimation accuracy [15].

Principal Component Analysis (PCA) serves as a prominent statistical method for understanding the significance of variance in skin conditions. Pardo et al. have successfully employed PCA to uncover the phenotypic correlation structure among seven features of facial aging. This analysis utilized data extracted from digital facial photographs and full-body skin examinations. The paper presented concludes that the analysis applied is not operator-dependent; rather, it is robust and objective [16]. Beyond merely measuring significance, PCA is routinely used for various tasks associated with the evaluation of cosmetic appearance. For example, in one study, Gabor filters and PCA were combined to implement an adaptive thresholding-based segmentation method for dermoscopic images. The authors have reported that their approach holds promise and could serve as a foundation for the development of more refined segmentation methods [17].

In addition to PCA there are several computational approaches for spectral reflectance reconstruction. Pseudo-inverse and finite-dimensional modelling are two of the widely implemented methods for estimation of the spectral reflectance of a surface from its observed color or reflectance. In one study Shen et al. have combined Wiener estimation, pseudo-inverse, and finite-dimensional modelling to reconstruct reflectance for multi-spectral imaging. Study reveals that proposed method would outperform those of the three techniques [**?**]. Although the study is not particularly focused on dermatological observation, presented results still would be promising for monitoring skin conditions.

## 4. Conclusion

The high accuracy and objective evaluation of skin features like wrinkles, pigmentation, and dark circles, are of great importance for dermatological research. Many instrumentation-based approaches, such as chromametry and spectrophotometers, have been developed to measure and accurately characterize skin appearance. These approaches have been supported by computer-based methods like Wiener estimation, PCA, pseudo-inverse, and finite-dimensional modeling. The integration of these hardware and software approaches has enabled clinicians and researchers to accurately and objectively evaluate the skin health and treatment efficacy. Supporting diverse instrumentation approaches adapted to this field, along with algorithmic methods, serves as a basis for the development of versatile, cost-effective, and efficient tools for future dermatological studies and applications.

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