http://www.moderntechno.de/index.php/meit/article/view/meit41-02-080
DOI: 10.30890/2567-5273.2025-41-02-080

PERSONALIZED DIAGNOSTICS IN NAIL CARE: FROM VISUAL ASSESSMENT TO INSTRUMENTAL ANALYSIS

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Abstract. *The article focuses on the issue of personalized diagnostics in nail care. The purpose of the study is to scientifically substantiate the effectiveness of personalized diagnostics that combines visual assessment and instrumental analysis. A critical review of the scientific literature, synthesis of information, systematization, and generalization of data were carried out using a structural-functional approach. The findings show that a personalized approach to nail diagnostics is based on a comprehensive understanding of nail biomarkers as indicators of the body's overall condition. The study proves that the combination of clinical, morphological, and technological parameters allows the development of individual care strategies tailored to nail diagnostics. It is demonstrated that this diagnostic system ensures a shift from standardized cosmetic procedures to scientifically grounded solutions that take medical risks into account. Personalized diagnostics form the basis for preventing damage, preserving the integrity of the nail plate, and maintaining clients' long-term health. The analysis highlights that visual assessment accounts for about 40% of diagnostic accuracy, therefore the expansion of diagnostic capabilities through instrumental methods is essential. It is revealed that the use of optical coherence tomography, ultrasound, MRI, Raman spectroscopy, and molecular analysis enables both quantitative and qualitative evaluation of nail conditions. The study shows that the use of digital technologies, including machine vision and artificial intelligence, increases diagnostic accuracy. The practical significance of this research lies in establishing a theoretical and methodological foundation for implementing personalized diagnostics in manicure practice, promoting the development of safe and evidence-based care technologies.*

Keywords: *personalized diagnostics, nail plate, instrumental analysis, visual assessment, biomarker.*

Introduction

The condition of nails reflects not only aesthetic aspects of appearance but also the overall state of human health. Nails respond to systemic metabolic and dermatological changes in the body, becoming natural indicators of internal organ dysfunction or metabolic disorders. Therefore, nail diagnostics carry a dual meaning: medical and cosmetological. Within the modern beauty industry, diagnostics serve as a key tool for ensuring safe care and preventing complications. This is achieved through an individually selected set of procedures. Understanding morphological, structural, and visual nail changes allows the detection of early signs of conditions such as onychomycosis, psoriasis, anemia, or endocrine disorders, which may appear before clinical symptoms of serious diseases develop.

With the advancement of technology and the growing adoption of personalized body care approaches, the role of nail diagnostics has significantly increased. Modern tools – from optical coherence tomography to artificial intelligence systems – make it possible to transform simple observation into precise, evidence-based evaluation. This not only helps to detect pathologies but also enables the creation of personalized care strategies that consider each client's individual characteristics. Under these conditions, diagnostics become the foundation of professional competence for a manicurist who integrates aesthetics, safety, and evidence-based practice.

Literature Review

The topic of personalized diagnostics in nail care – from visual assessment to instrumental analysis – has been widely explored in international scientific literature. Modern publications demonstrate notable progress in shifting from traditional visual examination methods to the use of artificial intelligence, machine vision, and spectroscopic technologies that provide more accurate, rapid, and objective evaluation of nails as diagnostic markers of various pathologies. Significant contributions have been made by researchers A. Aldana, R. Mayordomo, and F. Tejedor [2], who emphasize the limitations of clinical evaluation without laboratory or instrumental confirmation, underlining the need to integrate digital technologies into podiatric practice. A major role in shaping the new diagnostic paradigm has been played by Z. Li and colleagues [5], who summarized trends in the application of artificial intelligence algorithms in dermatology, including nail image analysis. This topic has been further developed by V. Gaurav, C. Grover, M. Tyagi, and S. Saurabh [4], who systematized the experience of using artificial intelligence for assessing nail pathologies, highlighting the potential of automated systems to improve diagnostic accuracy. Another research direction focuses on identifying systemic diseases through nail condition. J. Fan et al. [3] described biochemical changes in nail structures associated with diabetes mellitus, while J. R. Navarro-Cabrera and co-authors [6] proposed a machine vision model for non-invasive detection of iron deficiency. Innovative nail analysis technologies were demonstrated by T. Tabasz et al. [12], who evaluated the potential of Raman spectroscopy for diagnosing dermatological and systemic disorders.

The historical development of instrumental analysis approaches can be traced in studies by B. Richert [8] and U. Wollina with colleagues [13], who described early attempts to introduce instrumental examination methods into clinical practice. In the context of instrumental monitoring, it is worth noting the experimental approach by S. A. Saleah et al. [9], who used optical coherence tomography to analyze nail plate changes after cosmetic procedures. Another important area of progress is the development of automated pathology detection systems, as presented in the work of G. Shandilya et al. [10], who developed a hybrid CNN model for autonomous recognition of nail diseases. The most recent study by C. Agostini et al. [1] demonstrated the practical use of deep learning in diagnosing onychomycosis, indicating an active shift toward personalized intelligent systems in nail care.

Despite the considerable number of publications covering various aspects of personalized diagnostics in nail care, there remains a lack of systematized material that integrates clinical, instrumental, and algorithmic approaches. Therefore, by applying different methods of scientific cognition, an analysis, generalization, and grouping of existing findings have been conducted, allowing the topic to be presented in a comprehensive, interdisciplinary context.

The purpose of the article is to scientifically substantiate personalized diagnostics in nail care as an integrated approach that combines visual assessment and instrumental analysis to individually determine the condition of the nail plate and select safe care methods. To achieve this goal, the study performs three ***tasks***: first, to reveal the features of the personalized diagnostics concept in the nail service industry; second, to characterize the main criteria of visual assessment and determine their significance in forming an initial diagnostic conclusion; third, to analyze modern directions of instrumental nail analysis and their potential in improving the accuracy and efficiency of personalized care.

Research Results

The concept of personalized diagnostics in nail care is based on an individualized approach to evaluating the nail plate condition, taking into account the body’s physiological, biochemical, and systemic characteristics. This approach involves using scientifically grounded methods to identify changes that reflect both local damage and general metabolic or endocrine disorders. Personalization in diagnostics lies in the combination of visual, instrumental, and digital technologies to create an individual nail health profile, allowing the selection of the safest and most effective care strategy.

As noted by Fan J., this approach aligns with the modern trend toward precision medicine and individualized cosmetology aimed at preventing damage and improving overall nail health [3]. Personalized diagnostics rely on the understanding that nails are not only cosmetic features but also biomarkers of systemic body changes. It has been established that the composition and structure of nails reflect metabolic processes, including those associated with diabetes, cardiovascular, or endocrine disorders. Studies [3,4,8,10,12] show that nails can serve as a stable and painless material for non-invasive monitoring of patients with chronic diseases, such as diabetes, since they can accumulate biochemical markers over time. The advantage of personalized diagnostics lies in its ability to integrate individual client data with instrumental and digital analysis results, creating a holistic profile of nail health. This ensures precise differentiation between cosmetic changes and pathological deviations, helps avoid unnecessary interventions, and provides a scientifically grounded basis for safe care.

Thus, the personalized approach to nail diagnostics represents a transition from visual assessment to a comprehensive analysis system that combines biological, technological, and algorithmic knowledge to improve the quality and safety of procedures [1].

Before performing a manicure, it is necessary to examine the nails, as visual assessment serves as the primary stage of personalized diagnostics. This evaluation helps determine the overall condition of the nail plate, the surrounding skin, and identify possible pathological changes that may contraindicate cosmetic procedures. Such an examination allows the manicurist not only to assess the aesthetic aspect but also to prevent potential complications associated with hidden infections or systemic disorders. The main criteria of visual nail diagnostics include the following:

1) *Color and pigmentation of the nail plate*. Healthy nails have a uniform pink

tone with a whitish free edge, which indicates adequate blood supply and a normal keratin structure (Reinecke et al., 2020). Any color deviations – such as whitening (leukonychia), darkening, or the appearance of spots – may indicate both local and systemic disorders. For instance, Mees' or Muehrcke's lines are typical markers of intoxication or hypoalbuminemia [11].

2. *Shape, structure, and integrity of the nail.* Curvature, spoon-shaped nails (koilonychia), thickening, splitting, or cracks can be visually detected. Transverse ridges (Beau's lines), for example, appear after stressful or painful events that temporarily disrupt nail growth [11]. Such manifestations are important for specialists, as they may signal general metabolic or hormonal disorders.

3. *Condition of the cuticle, nail bed, and free edge.* According to Reinecke et al. [7], a healthy nail has an attached cuticle, a smooth surface, and a moderately curved free edge. Excessive trimming or damage to the cuticle disrupts its barrier function and facilitates pathogen entry, so these structures must remain intact during manicure procedures.

4. Signs of pathological and inflammatory changes. Visual symptoms such as nail detachment from the bed (onycholysis), subungual spots, changes in transparency, or thickening may indicate fungal infection. However, clinical examination alone has limited accuracy – according to a survey of 415 podiatrists, only about 40% of visual onychomycosis diagnoses were correct without additional tests [2]. This confirms that visual assessment has a high rate of false-positive results and must be supplemented by laboratory or instrumental methods.

5. *Detection of systemic manifestations in nails.* many nail changes serve as indicators of general systemic diseases. For instance, Terry's nails may signal cirrhosis or heart failure, while clubbing (thickened fingertips with curved nails) is often observed in chronic pulmonary or oncological conditions [11]. For a manicurist, this means that even a cosmetic procedure requires basic awareness of medical signs to avoid working with affected tissues.

6. *Evaluation of the effects of decorative interventions.* Visual diagnostics can also reveal damage caused by cosmetic manipulation. A study using optical coherence

tomography showed that 72 hours after nail-art removal, microcracks and white spots appeared in subsurface nail layers [9]. Such changes are often invisible to the naked eye but can be detected through careful visual examination.

However, as noted by U. Wollina et al. [13], clinical examination alone is not sufficiently accurate for diagnostics, and since visual assessment of nails often lacks precision, instrumental research methods are gaining increasing importance in modern practice. Their purpose is to transform subjective impressions of the nail's appearance into objective measurable indicators that define morphological, physicochemical, and functional parameters of the nail plate and surrounding tissues. For manicurists, such methods are of practical value, as they help distinguish superficial cosmetic changes from pathological ones, prevent trauma to weakened nail structures, and select an individual care strategy.

Among instrumental research methods, the most widely used are optical coherence tomography (OCT), ultrasound diagnostics, magnetic resonance imaging (MRI), Raman spectroscopy, and advanced digital technologies such as machine vision and artificial intelligence. Each of these approaches offers unique capabilities for analyzing nail conditions and provides varying levels of insight into the structure and chemical composition of tissues.

Optical coherence tomography (OCT) is a non-invasive optical technique that produces highly accurate cross-sectional images of the nail plate in real time. Its principle is based on measuring the delay of reflected infrared light, which makes it possible to obtain detailed images of internal nail layers with a resolution of 1–15 micrometers – 10 to 100 times more precise than traditional ultrasound [9]. This method allows detection of microcracks, defects, and hidden damage resulting from decorative procedures or mechanical stress. For nail care professionals, this is particularly valuable as it enables the identification of nail damage depth before it becomes visible to the naked eye, thus preventing further destruction of the nail plate.

Ultrasound diagnostics, according to Richert [8], is one of the most accessible non-invasive methods for nail examination. It is based on the analysis of sound waves reflected from different tissue structures, allowing evaluation of nail plate thickness, detection of subungual formations (such as glomus tumors or cysts), and identification of vascularization in pathological areas using color Doppler imaging. For manicurists, such data are crucial when the nail shows swelling, tenderness, or surface irregularities, as this helps distinguish superficial cosmetic defects from deeper pathologies that require medical attention.

In addition to ultrasound, magnetic resonance imaging (MRI) is used in complex cases to detect vascular formations, cysts, and tumors, as well as to accurately determine their localization prior to surgical intervention [8]. Although MRI is less applicable in everyday cosmetic practice due to its high cost and technical complexity, its principles serve as a foundation for developing more compact optical technologies, particularly OCT.

Another modern method, Raman spectroscopy, is based on the phenomenon of inelastic light scattering, which makes it possible to record molecular vibrational states. As noted by Tabasz et al. [12], this approach creates a “molecular fingerprint” of each sample, reflecting its chemical composition and structural changes. This enables the analysis of keratinization levels, disulfide bond content, and the presence of pathological metabolites or alterations caused by systemic diseases. For a nail care professional, such a technology could potentially serve as a diagnostic guide for determining the degree of nail weakening, detecting hidden damage after chemical exposure, or assessing the effectiveness of restorative treatments.

Instrumental approaches also include molecular diagnostic methods, particularly polymerase chain reaction (PCR), which allows the detection of dermatophyte or other pathogen DNA without the need for culture growth. These technologies, known from dermatological research, are gradually being adapted for cosmetic diagnostics as a rapid way to confirm fungal or bacterial infections. For a manicurist, knowledge of PCR capabilities is important as it helps guide the client toward medical examination in case of suspected infection before performing coating or polishing procedures.

A separate field is occupied by digital technologies—machine vision and artificial intelligence systems – which are increasingly used for automatic detection of nail pathologies based on photographic images. Modern hybrid neural networks, as demonstrated by Shandilya et al. [10], can classify up to six types of nail disorders with an accuracy exceeding 99%. The algorithms analyze shape, color, texture, and subtle surface anomalies that are invisible to the human eye, providing a preliminary diagnostic suggestion. This opens up prospects for developing portable mobile applications for nail care professionals that would allow quick assessment of a client's nail condition before procedures.

The advancement of computer vision and high-quality photography has made such technologies more accessible. Research by Navarro-Cabrera et al. [6] showed that even high-resolution smartphones (108 MP) can be used for non-invasive nail analysis and detection of iron deficiency through machine learning algorithms. For a manicurist, this means a potential opportunity to introduce simple digital screening tools that help evaluate nail conditions without complex equipment. The key instrumental approaches to personalized nail diagnostics are summarized in Table 1.

Table 1 – Instrumental approaches to personalized nail diagnostics

Instrument name	Information provided / what it allows to detect
Optical coherence tomography (OCT)	microcracks, subsurface defects, changes in nail thickness and structure after cosmetic or mechanical exposure [8,9]
High-frequency ultrasound (HFUS)	nail plate thickness, presence of subungual formations, cysts, tumors, and vascularization of pathological areas [9]
Magnetic resonance imaging (MRI)	vascular lesions, glomus tumors, cysts, and deep structural changes in the nail [9]
Raman spectroscopy	chemical composition of the nail, keratinization level, changes in protein structures, markers of systemic or dermatological diseases [12]
Molecular diagnostics (PCR)	confirmation of fungal or bacterial infections, identification of pathogen type [9]
Computer vision and artificial intelligence (AI)	recognition of nail pathologies such as anemia, psoriasis, or onychomycosis; evaluation of nail condition before procedures [6,9]

Note: systematized by the author

Thus, instrumental diagnostics expand the possibilities of nail assessment far beyond traditional visual observation. They provide quantitative, objective, and reproducible data, enable early detection of microstructural and biochemical changes, and help determine the safety and appropriateness of cosmetic interventions. For a nail care professional, this means not only improving service quality but also fulfilling professional responsibility – knowing when a nail requires decorative correction and when it needs medical attention.

Conclusions

Therefore, the personalized approach to nail diagnostics integrates clinical, aesthetic, and technological aspects of care. This makes it possible to view nails not merely as an element of appearance but as an important indicator of the body's overall condition. The essence of personalization lies in considering morphological, biochemical, and systemic characteristics, allowing a transition from standard cosmetic procedures to scientifically grounded solutions that take medical risks into account based on the assessment of tissue health and potential pathologies.

Such diagnostics make it possible to develop individualized care strategies and, in some cases, even therapeutic approaches. Both visual observation and instrumental methods are used for diagnostics. Visual analysis allows a manicurist to quickly detect signs of abnormalities, including changes in color, shape, structure, or nail plate integrity. The condition of the cuticle, nail bed, and surrounding skin is also evaluated. This examination helps identify pathological manifestations such as fungal infections, psoriatic changes, or the effects of trauma.

However, not all visual diagnoses are sufficiently accurate, so manicurists must combine them with instrumental diagnostics. The latter form the foundation of the modern personalized approach, which involves the use of optical coherence tomography, ultrasound, magnetic resonance imaging, Raman spectroscopy, and molecular analysis methods. Digital technologies, including machine vision and artificial intelligence, enable automated assessment.

In this way, nail care professionals create conditions that ensure professional safety, help prevent injury to weakened or pathologically altered nails, and provide a scientific basis for choosing appropriate cosmetic procedures.

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Issue №41
Part 2
October 2025

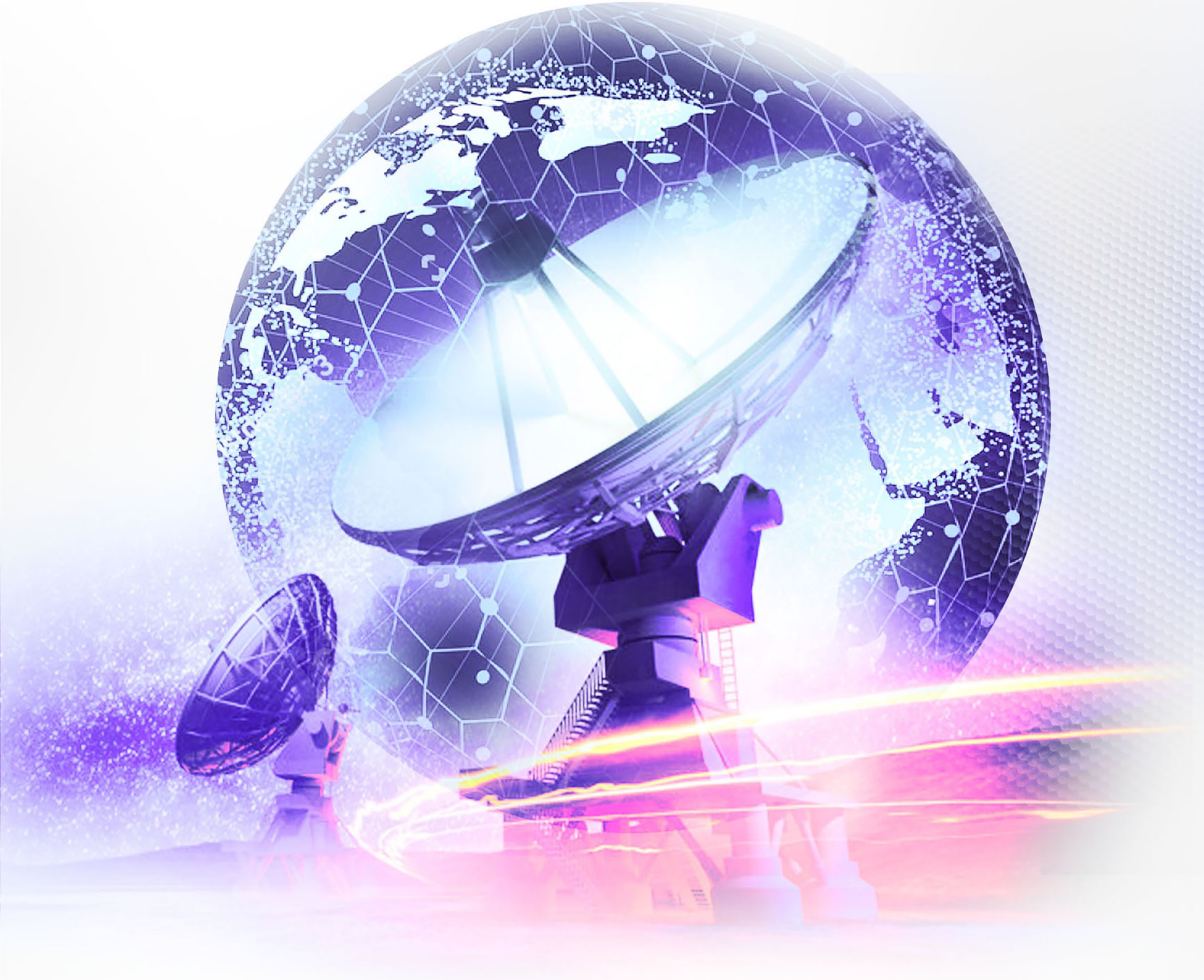
Development of the original layout - Sergeieva&Co

Signed: October 30, 2025

Sergeieva&Co
Lußstr. 13
76227 Karlsruhe
e-mail: editor@moderntechno.de
site: www.moderntechno.de

Articles published in the author's edition

ISSN 2567-5273



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