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MODERN INNOVATIVE APPROACHES IN DERMATOVENEREOLOGY: TELEDERMATOLOGY, MOLECULAR DIAGNOSTICS, AND NOVEL THERAPEUTIC STRATEGIES

Allaeva M. D.¹

Khudayarova D.²,

Allaeva K. B.³

¹Associate Professor, Department of Therapeutic Disciplines,
Kimyo International University in Tashkent, Uzbekistan

²4th-year Student, Faculty of General Medicine,

Kimyo International University in Tashkent, Uzbekistan

³Master's Student, Department of Public Health,
Westminster International University in Tashkent

Abstract

This article presents an in-depth analysis of modern innovative directions in dermatovenereology, with a focus on tele dermatology, molecular genetic and epigenetic diagnostics, as well as novel therapeutic strategies. Based on data from international and domestic studies from 2020–2025, it is demonstrated that the integration of digital technologies, high-precision molecular methods, and targeted therapy is forming a new paradigm of personalized dermatological care. Clinical, organizational, and prognostic aspects of implementing these approaches are discussed.

Keywords: Tele dermatology, molecular diagnostics, innovative therapeutic approaches, dermatovenereology, personalized medicine.

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Introduction

In recent years (2020–2025), dermatovenereology has undergone transformative innovations in teledermatology, molecular diagnostics, and therapeutic strategies driven by technological and scientific advances. Classical clinical and morphological diagnostic methods are increasingly complemented by high-precision molecular and genomic studies, while treatment standards are shifting toward targeted and personalized approaches.

These changes gained particular significance during the COVID-19 pandemic, when telemedicine technologies became an integral part of dermatological care delivery. This review analyzes scientific data from 2020–2025 on the implementation of telemedicine, molecular diagnostic tools, and therapeutic approaches for dermatological and venereological conditions.

The **aim** of this work is to systematize and provide an expert interpretation of current data on teledermatology, molecular diagnostics, and innovative therapeutic strategies, taking into account both international and domestic experience.

Methods

A literature review was conducted using databases such as PubMed, Scopus, and Web of Science. Search keywords included “teledermatology,” “molecular diagnostics in dermatology,” and “novel therapies in dermatovenereology” for articles published between 2020 and 2025. Inclusion criteria: peer-reviewed studies in English or with English abstracts.

Exclusion criteria: irrelevant studies or those published before 2020.

A total of 14 key references were selected for analysis.

Results

Teledermatology represents one of the most rapidly developing areas of telemedicine. The high visual accessibility of skin diseases makes dermatology particularly suitable for remote consultation formats.

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Three main models are distinguished:

Asynchronous (store-and-forward, SAF) — transmission of clinical images and anamnestic data for subsequent expert evaluation, avoiding unnecessary visits [1].

Synchronous (real-time teledermatology, RT-TD) — consultation via video communication; facilitates live interaction, closely simulating in-person consultations.

Hybrid model (SAF + RT-TD), including mobile teledermatology and teledermatoscopy, enabling real-time monitoring regardless of location. The main parameters of the three teledermatology models are structured in Table №1.

Table №1. Teledermatology Modalities

Modality	Description	Key Advantages	Examples from Studies
Asynchronous (SAF)	Transmission of images/descriptions for later review	Flexibility, time efficiency	Nevus assessment [1]
Synchronous (RT-TD)	Live video consultations	Real-time interaction	Simulates in-person visits
Hybrid/Mobile	Combination via applications	Accessibility in remote areas	89% adoption among young dermatologists [2]

According to international studies, asynchronous teledermatology demonstrates high diagnostic accuracy for skin neoplasms, inflammatory dermatoses, and acne, significantly reducing waiting times for consultations [1–4, 8–11]. Russian authors emphasize its importance for regions with limited access to dermatological care [5–7]. Adoption rates are high: more than 50% of Australian dermatologists use mobile teledermatology weekly, increasing to 89% among trainees [2]. Advantages include improved access for rural and

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socioeconomically vulnerable patients, reducing barriers such as mobility limitations and scheduling constraints [4].

During the COVID-19 pandemic, 92.3% of patients with acne reported satisfaction with physician attention in tele dermatology consultations, and 86.5% were satisfied with session duration [3]. Advanced techniques such as “tape TD” and “drop TD” improve diagnostic quality [4]. Overall, tele dermatology optimizes triage (the process of prioritizing patients based on urgency), accelerates care delivery, and supports general practitioners in prioritizing urgent cases.

Challenges and AI Integration. Challenges include variability in image quality and data security; however, integration with artificial intelligence (AI) for preliminary analysis shows promise for future scalability.

According to a study by Esteva et al., published in *Nature* (2017), diagnostic performance of a neural network was directly compared with that of practicing dermatologists. The network, based on the GoogLeNet Inception v3 architecture, was trained to recognize skin diseases from images using a dataset of over 127,000 images, including both clinical and dermoscopic photographs.

For testing, biopsy-confirmed cases were used. Both the neural network and dermatologists with more than 20 years of experience were asked to determine patient management strategies based solely on visual information (biopsy recommendation, treatment, or reassurance). Lesions were classified as malignant or benign.

Performance comparison using ROC curves demonstrated that, on average, the neural network achieved higher diagnostic accuracy than most dermatologists.

Thus, the study showed that artificial intelligence can not only reach but sometimes surpass specialist-level performance in recognizing skin pathologies, highlighting its potential as a decision-support tool in dermatology.

Another example of successful AI application is the use of **convolutional neural networks (CNNs)** for automated diagnosis of facial acne. Studies demonstrated

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high classification accuracy (>85%) for different lesion types, including comedones, papules, pustules, and cystic elements. Such algorithms: accelerate skin condition assessment, reduce diagnostic subjectivity, enable personalized therapeutic strategies.

Integration into teledermatology services opens opportunities for **remote monitoring and personalized acne management** (Sci Rep. 2018;8:5839).

Mobile Applications in Dermatology. Modern mobile applications are becoming an important tool in clinical dermatology, contributing to improved diagnostics, professional education, and patient monitoring. As noted by the editor of JAMA Dermatology (2005), visual clinical diagnosis of skin conditions is increasingly taking precedence, reducing the need for biopsies and histopathological examinations [1].

One example is a study by Sangers et al. (2023), which evaluated a CE-certified smartphone application for identifying melanoma-suspected lesions. The application was compared with experienced dermatologists and 2D/3D CNN algorithms.

Although useful, results showed a tendency toward **over-detection**, identifying many benign nevi as suspicious. This highlights that such tools should be used cautiously and primarily as screening aids rather than replacements for clinical evaluation.

Applications such as **SkinVision** assist in assessing the risk of skin lesions for early melanoma detection. However, their diagnostic accuracy remains limited:

- Sensitivity \approx 88% (95% CI 70–98%)
- Specificity \approx 79% (95% CI 70–86%)

This indicates good detection of suspicious lesions but a relatively high rate of false positives.

In a study by Ngoo et al. (2020), a machine learning-based application trained on over 131,000 images demonstrated:

- Sensitivity \approx 95%

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- Specificity $\approx 78\%$

These findings confirm the potential of such tools for preliminary screening but also highlight the need for further improvement before widespread clinical adoption.

A meta-analysis by Cherrez-Ojeda et al. (2024) showed that mobile applications and telemonitoring in atopic dermatitis significantly:

reduce disease severity (SCORAD, EASI)

improve treatment adherence

enhance quality of life

Patients: followed treatment recommendations more consistently, missed fewer treatments, showed reduced itching and fewer exacerbations

Limitations of Tele dermatology. Despite its advantages, concerns remain regarding:

1. data confidentiality
2. communication quality
3. completeness of transmitted information
4. technological barriers

Some studies indicate that telemedicine consultations may be longer than in-person visits, and diagnostic confidence may be lower in asynchronous models.

Although tele dermatology is more cost-effective overall, especially considering travel distance and clinic workload, in-person dermatology still demonstrates higher diagnostic and therapeutic accuracy.

A systematic review by Chow et al. (2024) reported diagnostic concordance rates of **70–90%** compared to in-person consultations, particularly for inflammatory conditions such as acne, psoriasis, and atopic dermatitis. High patient satisfaction was associated with: convenience, time savings, reduced transportation costs, improved access to care.

Tele dermatology should not be considered a replacement for in-person care but rather an effective complement to traditional dermatological services. It

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significantly enhances accessibility, optimizes triage, and improves healthcare delivery, especially in remote regions.

Clinical Effectiveness and Patient Satisfaction. Studies demonstrate a high level of patient satisfaction with tele dermatology services—over **85–90%**, which is comparable to in-person consultations [3, 10]. An important advantage is the possibility of **primary triage by general practitioners**, followed by referral to a dermatologist when necessary [5, 6]. Thus, tele dermatology is considered not as a replacement for face-to-face consultations, but as an effective complement to the traditional dermatological care system.

Molecular Diagnostics: precision in Identifying Skin Pathologies. The development of molecular genetics methods has significantly expanded the diagnostic capabilities of dermatology, particularly in the fields of **genodermatoses, oncodermatology, and chronic inflammatory skin diseases**. Molecular diagnostics enables the detection of **genetic, epigenetic, and molecular alterations** in skin diseases, supporting diagnosis, prognosis, and therapy selection.

The main methods include: NGS, PCR/qRT-PCR, FISH, CGH/SNP-array, Epigenetic analysis.

NGS (Next-Generation Sequencing): NGS has become a key diagnostic tool for inherited skin diseases, providing high-throughput sequencing of DNA fragments and overcoming the limitations of PCR in genodermatoses. It has advanced understanding of: epidermolysis bullosa; ichthyosis; squamous cell carcinoma mutation landscapes; melanoma (e.g., BRAF mutations); cutaneous T-cell lymphoma. NGS also enables evaluation of **tumor mutational burden**, which is critical for prognosis and therapy selection [8, 9].

PCR/qRT-PCR (Polymerase Chain Reaction): PCR remains a fundamental method for diagnosing infectious dermatoses by amplifying DNA/RNA to detect pathogens. Large-scale studies demonstrate:

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- Sensitivity: **94.6%**
- Accuracy: **98.5%**

Primarily used for detecting *Trichophyton rubrum*, allowing faster diagnosis and improved therapy selection. Additional methods such as MALDI-TOF or sequencing may refine results [10,16].

FISH (Fluorescence In Situ Hybridization): FISH visualizes chromosomal abnormalities using fluorescent probes. In ambiguous melanocytic lesions: targets genes such as **RREB1 and CCND1**; confirms melanoma in positive cases; may produce false positives in nevi. Therefore, it is best used as a **complement to histopathology** [11].

CGH/SNP-Array: These methods detect **copy number variations (CNVs)** without the need for cell culture. Applications in melanocytic tumors:

1. Melanoma: gains in **1q, 6p**, losses in **9p**
2. Nevi/Spitz nevi: gain in **11p**

This significantly improves diagnostic accuracy in ambiguous cases [12,13].

Epigenetic Analysis. Epigenetic techniques (DNA methylation, histone modifications, ATAC-seq) have revealed a key role of **epigenetic dysregulation** in: cutaneous T-cell lymphoma; other skin malignancies. These findings open new possibilities for **therapeutic targeting** [14]. The main characteristics, applications, and limitations of these methods are presented in Table № 2.

Table № 2. Molecular Diagnostic Methods

Method	Applications in Dermatology	Sensitivity/Accuracy	Limitations
NGS	Genodermatoses, cancers	High throughput	Expensive, data-intensive
PCR/qRT-PCR	Infections (e.g., dermatophytosis)	94.6% sensitivity [10]	Requires specific primers
FISH	Melanoma differentiation	Detects chromosomal abnormalities	False positives [11]
CGH/SNP-Array	Tumor profiling	Identifies CNVs	Less sensitive to point mutations
Epigenetic Analysis	Lymphoma, inflammatory diseases	Reveals dysregulation	Complex interpretation

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Biological Markers. Due to the active integration of molecular biomarkers into modern dermatovenereology, genetic markers such as mutations in COL7A1, KRT5/KRT14, and FLG are increasingly used for the precise identification of inherited skin disorders (genodermatoses) [Tan et al., 2023]. In inflammatory and autoimmune dermatoses, key roles are played by the JAK–STAT signaling pathway and cytokines including IL-4, IL-13, TNF- α , and IL-17, enabling the targeted use of JAK inhibitors and biological agents [Tan et al., 2023–2024]. These biomarkers demonstrate high clinical value for the selection of personalized therapeutic strategies and for monitoring treatment efficacy, allowing prediction of disease severity and optimization of therapeutic approaches.

In inflammatory and autoimmune dermatoses, the activity of the JAK–STAT pathway and associated cytokines (IL-4, IL-13, TNF- α , IL-17) guides the use of JAK inhibitors (e.g., ruxolitinib) and biologic therapies (e.g., dupilumab, IL-17/IL-23 inhibitors). In oncodermatology, biomarkers such as mutations in BRAF, NRAS, and KIT, as well as loss of CDKN2A, support the application of targeted therapies (BRAF inhibitors, CDK4/6 inhibitors) and immunotherapy, thereby improving treatment outcomes in melanoma. Molecular profiling and differentiation between malignant and benign lesions are achieved using techniques such as next-generation sequencing (NGS), fluorescence in situ hybridization (FISH), CGH/SNP-array, and epigenetic analysis (including DNA methylation and histone modifications). These approaches contribute to improved prognostic assessment, selection of personalized therapy, and optimization of clinical outcomes. The integration of these biomarkers forms the foundation of precision dermatology, enhancing diagnostic accuracy and therapeutic effectiveness. These advances are driving the development of personalized medicine, improving both diagnostic precision and treatment outcomes, while future directions emphasize their integration to further enhance patients' quality of life.

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Novel Therapeutic Strategies: Targeting Molecular Pathways. Between 2020 and 2025, therapeutic approaches have evolved to address the underlying mechanisms of inflammatory, autoimmune, and oncological skin diseases.

JAK–STAT Pathway Inhibition. One of the most significant advances in recent years has been the introduction of Janus kinase (JAK) inhibitors. These agents provide rapid and pronounced anti-inflammatory effects by blocking key cytokine signaling pathways. JAK inhibitors (both oral and topical) suppress multiple pro-inflammatory cytokines in conditions such as atopic dermatitis, psoriasis, alopecia areata, vitiligo, lichen planus, dermatomyositis, graft-versus-host disease, and cutaneous lupus. Their multi-target mechanism of action enables rapid reduction of inflammation, and their prior approval for related arthritic conditions has paved the way for broader dermatological applications [15,18,19].

Targeting CDKN2A Loss in Melanoma. Loss of the CDKN2A gene and associated dysregulation of the cell cycle represent promising therapeutic targets. Combination strategies involving CDK4/6 inhibitors and immunotherapy may enhance treatment efficacy and help overcome drug resistance.

Innovations in Vitiligo Treatment. Topical ruxolitinib (a JAK1/2 inhibitor) has been approved in the United States and Europe for patients with facial involvement and $\leq 10\%$ body surface area, demonstrating effective repigmentation, particularly when combined with narrowband UVB phototherapy [19]. Emerging therapeutic approaches include targeting the IL-15/CD122 pathway to suppress T-cell memory, inhibition of HSP70i to prevent disease initiation, MMP-9 blockade to promote melanocyte retention, modulation of the skin microbiome, and activation of the WNT signaling pathway for acral and hair-bearing areas.

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Other Biologic Therapies. Dupilumab, an IL-4 and IL-13 inhibitor, has demonstrated high efficacy, favorable tolerability, and long-term safety in patients with moderate-to-severe atopic dermatitis (Blauvelt et al., 2022).

Table №: 3 Targeted Therapies

Disease	Key Therapy	Mechanism	Evidence (2020–2025)
Inflammatory dermatoses	JAK inhibitors	Cytokine signaling blockade	Effective in psoriasis, atopic dermatitis
Melanoma	CDK4/6 inhibitors	Cell cycle arrest	Targeting CDKN2A loss
Vitiligo	Ruxolitinib	JAK1/2 inhibition	Repigmentation in clinical trials
Atopic dermatitis	Dupilumab	IL-4/IL-13 blockade	Long-term efficacy and safety

Table №3 presents current targeted therapeutic approaches in dermatology, specifying the associated diseases, mechanisms of drug action, and supporting clinical evidence from 2020–2025. The table illustrates how JAK inhibitors, CDK4/6 inhibitors, ruxolitinib, and biologic agents such as dupilumab act on key molecular pathways to enable personalized treatment strategies for inflammatory, autoimmune, and oncological skin disorders.

Discussion

These innovations significantly improve **accessibility, diagnostic precision, and treatment effectiveness** in dermatovenereology. Tele dermatology addresses barriers to remote care, molecular diagnostics enable personalized approaches, and novel therapies such as JAK inhibitors provide safer and more effective treatment options.

However, several challenges remain:

1. data confidentiality
2. diagnostic accuracy

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3. equitable access to advanced technologies

Future integration of these approaches is expected to further improve clinical outcomes.

Conclusion

Modern dermatovenereology is evolving toward the integration of telemedicine technologies, molecular diagnostics, and targeted therapy. This interdisciplinary approach enables more accurate diagnosis, personalized treatment, and improved prognosis for chronic and oncological skin diseases. The implementation of these technologies in clinical practice requires further standardization, professional training, and the development of regulatory frameworks. Thus, the integration of digital technologies, molecular diagnostics, and targeted therapies establishes a new paradigm of personalized dermatological care, enhancing diagnostic precision, optimizing treatment, and improving patients' quality of life. Future directions include continued method standardization, specialist training, and the advancement of legal and regulatory frameworks to facilitate the adoption of innovative technologies in clinical practice.

The authors declare no conflicts of interest. This review complies with ethical guidelines for literature reviews; no human or animal subjects were involved.

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