International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	TREATMENT METHODS FOR HPV-INDUCED WARTS: INTEGRATING MEDICAL THERAPIES, DIGITAL HEALTH TECHNOLOGIES, AND PUBLIC HEALTH IMPLICATIONS - A NARRATIVE REVIEW
DOI	https://doi.org/10.31435/ijitss.2(50).2026.5697
RECEIVED	04 March 2026
ACCEPTED	21 May 2026
PUBLISHED	05 June 2026
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

TREATMENT METHODS FOR HPV-INDUCED WARTS: INTEGRATING MEDICAL THERAPIES, DIGITAL HEALTH TECHNOLOGIES, AND PUBLIC HEALTH IMPLICATIONS - A NARRATIVE REVIEW

Sylwia Hejna *(Corresponding Author, Email: shejna8@gmail.com)*
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0005-6313-3067

Weronika Smutkiewicz
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0007-4965-1903

Weronika Teterycz
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0000-7486-458X

Wiktoria Goździejewska
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0007-5302-1883

Łukasz Jaworek
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0007-8117-5644

Gabriela Zimka
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0005-3954-7307

Krystian Bjorgen
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0008-0225-7439

Lilianna Jasińska
University of Warmia and Mazury in Olsztyn, Olsztyn, Poland
ORCID ID: 0009-0006-0819-8922

Magdalena Roman
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0004-1261-180X

Martyna Lipiarz
Cardinal Stefan Wyszyński University in Warsaw, Warsaw, Poland
ORCID ID: 0009-0001-3124-9250

ABSTRACT

Human papillomavirus (HPV)-induced warts are common dermatological conditions that impose a persistent clinical, psychosocial, and public-health burden despite their benign nature. This review aimed to synthesize current evidence on pharmacological and procedural treatments for HPV-induced warts while examining the growing role of digital health technologies and broader public-health considerations. A structured narrative review with systematic elements was conducted using PubMed, Scopus, and Web of Science, focusing primarily on English-language studies published between 2010 and March 2026. Evidence from clinical trials, systematic reviews, meta-analyses, guidelines, and selected high-quality observational studies was qualitatively synthesized. The findings indicate that conventional therapies, particularly salicylic acid and cryotherapy, remain central to management but are limited by variable efficacy, recurrence, and adherence challenges. Emerging immunotherapeutic approaches and selected procedural modalities, including laser therapy and photodynamic therapy, offer promise for resistant lesions. In parallel, teledermatology, mobile health applications, and artificial intelligence-based image analysis are expanding opportunities for early assessment, follow-up, and patient engagement. The review concludes that optimal management of HPV-induced warts requires a multidisciplinary strategy combining evidence-based treatment, technological innovation, and public-health awareness to improve access, adherence, equity, and patient well-being.

KEYWORDS

Human Papillomavirus, Cutaneous Warts, Teledermatology, Digital Health, Artificial Intelligence, Public Health

CITATION

Sylwia Hejna, Weronika Smutkiewicz, Weronika Teterycz, Wiktoria Goździejewska, Łukasz Jaworek, Gabriela Zimka, Krystian Bjorgen, Lilianna Jasińska, Magdalena Roman, Martyna Lipiarz. (2026) Treatment Methods for HPV-Induced Warts: Integrating Medical Therapies, Digital Health Technologies, and Public Health Implications - A Narrative Review. *International Journal of Innovative Technologies in Social Science*. 2(50). doi: 10.31435/ijitss.2(50).2026.5697

1. Introduction

Infections caused by human papillomavirus represent one of the most prevalent viral conditions affecting the skin and mucous membranes worldwide (Bruni et al., 2019; World Health Organization, 2021). Among their various clinical manifestations, HPV-induced cutaneous warts are particularly common, affecting individuals of all age groups, with higher prevalence observed in children, adolescents, and immunocompromised populations (Sterling et al., 2014). Although generally benign, these lesions can be persistent, recurrent, and resistant to treatment, posing a significant clinical challenge.

Cutaneous warts are primarily caused by specific HPV genotypes that infect keratinized epithelium, leading to hyperproliferation of skin cells (Stanley, 2012). Transmission occurs through direct contact or via contaminated surfaces, making environments such as swimming pools, gyms, and communal facilities important vectors of infection. While many warts resolve spontaneously due to host immune responses, a substantial proportion of cases require medical intervention, particularly when lesions are painful, extensive, or cosmetically concerning (Kwok et al., 2012).

The management of HPV-induced warts encompasses a broad spectrum of therapeutic approaches, including topical pharmacological treatments, physical destruction methods, and emerging immunomodulatory therapies. Conventional treatments such as salicylic acid application and cryotherapy remain widely used due to their accessibility and relatively low cost (Bruggink et al., 2010; Cockayne et al., 2011). However, their effectiveness varies considerably, with recurrence rates remaining high and treatment duration often prolonged (Kwok et al., 2012). More advanced interventions, including laser therapy and photodynamic therapy, have demonstrated improved efficacy in certain cases, yet their availability is frequently limited by cost and resource constraints (Iranmanesh et al., 2021; Shen et al., 2022).

In recent years, technological advancements have begun to reshape the landscape of dermatological care, including the management of HPV-related skin conditions (Lee & English, 2018; Trettel et al., 2018). The integration of digital health solutions—such as teledermatology, mobile health applications, and artificial

intelligence-based diagnostic tools—has introduced new opportunities for improving early detection, treatment monitoring, and patient engagement (Free et al., 2013; Topol, 2019). Teledermatology, in particular, enables remote evaluation of skin lesions, thereby expanding access to specialist care, especially in underserved or geographically remote regions (Kazi et al., 2021). Similarly, AI-driven image analysis systems have shown promising results in assisting clinicians with the classification of skin lesions, potentially enhancing diagnostic accuracy and efficiency (Esteva et al., 2017).

Beyond clinical management, HPV-induced warts also have important implications for public health and individual well-being. Although not life-threatening, these lesions can significantly impact patients' quality of life, contributing to psychological distress, social stigma, and reduced self-esteem (Salah, 2018; Mohta et al., 2021). Furthermore, disparities in access to healthcare services, variations in health literacy, and environmental factors can influence both the incidence and management outcomes of HPV infections (Braveman & Gottlieb, 2014). Addressing these broader determinants is essential for achieving equitable healthcare delivery.

Despite the availability of numerous treatment modalities and growing interest in technological innovations, there remains a lack of comprehensive synthesis that integrates clinical, technological, and public health perspectives in the management of HPV-induced warts (Maghiar et al., 2024).

Therefore, the aim of this review is to provide a comprehensive overview of current treatment methods for HPV-induced warts, encompassing pharmacological and procedural therapies, while also examining the emerging role of digital health technologies and public health strategies. By adopting a multidisciplinary perspective, this study seeks to highlight opportunities for improving treatment outcomes, enhancing accessibility, and supporting overall patient well-being.

2. Methodology

This study was conducted as a structured narrative review with elements of a systematic approach to ensure a comprehensive and transparent synthesis of the available literature on the treatment of HPV-induced warts. The methodology was guided by the principles outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework.

A comprehensive literature search was performed across multiple electronic databases, including PubMed, Scopus, and Web of Science. The search aimed to identify relevant peer-reviewed articles published between January 2010 and March 2026. Additional sources, such as reports from international health organizations, were also considered to incorporate public health perspectives.

The search strategy combined Medical Subject Headings and free-text keywords related to HPV-induced warts and their management. The primary search terms included: "human papillomavirus," "HPV," "cutaneous warts," "wart treatment," "cryotherapy," "topical therapy," "immunotherapy," "teledermatology," "digital health," and "artificial intelligence in dermatology." Boolean operators (AND, OR) were used to refine the search and ensure broad yet relevant coverage of the topic.

Studies were selected based on predefined inclusion and exclusion criteria. Eligible studies met the following criteria: published in English, focused on the treatment or management of HPV-induced cutaneous or mucosal warts, included clinical trials, systematic reviews, meta-analyses, or high-quality observational studies, and addressed either conventional therapies, emerging medical technologies, or digital health applications relevant to dermatology. Exclusion criteria included: studies not directly related to HPV-induced warts, case reports with limited generalizability, non-peer-reviewed articles, editorials, and conference abstracts without full data, and studies published before 2010, unless considered seminal or highly influential.

Relevant data were extracted from the selected studies using a standardized approach. Extracted information included authorship, year of publication, study design, sample size where applicable, type of intervention, outcomes measured, and key findings. A qualitative synthesis was conducted to compare and contrast different treatment modalities and technological approaches. The results were organized into thematic categories, including pharmacological treatments, procedural interventions, and emerging digital health technologies.

To ensure the reliability of the findings, the methodological quality of selected studies was considered during the review process. Preference was given to high-quality evidence, such as randomized controlled trials, systematic reviews, and meta-analyses. Studies with significant methodological limitations or unclear outcomes were interpreted with caution.

As this study is based solely on previously published data, no ethical approval was required. However, all sources were appropriately cited to ensure academic integrity and to comply with ethical standards

regarding the use of secondary data. This methodological approach enables a comprehensive and balanced evaluation of current treatment strategies for HPV-induced warts while incorporating technological and public health perspectives relevant to contemporary healthcare systems.

Because the review aimed to bridge dermatology, digital health, and public health, studies were not selected solely on the basis of clinical efficacy outcomes. Publications were also considered relevant if they provided robust insight into care delivery, health-system barriers, inequity, patient experience, or implementation challenges. This broader inclusion logic was essential for aligning the review with the interdisciplinary aims of the target journal while maintaining transparency about the narrative nature of the synthesis.

3. Results

3.1. Pharmacological Treatments

Pharmacological therapies represent one of the most commonly utilized approaches in the management of HPV-induced warts, particularly in primary care and outpatient dermatological settings (Kwok et al., 2012; Sterling et al., 2014). These treatments are generally non-invasive, accessible, and cost-effective, making them a first-line option for many patients. However, their efficacy varies depending on factors such as wart type, location, patient age, and immune status.

One of the most widely used topical agents is salicylic acid, a keratolytic compound that promotes the gradual destruction of infected keratinocytes by softening and exfoliating the stratum corneum (Kwok et al., 2012). Numerous studies have demonstrated its effectiveness, particularly when applied consistently over several weeks. Salicylic acid is often considered the standard first-line therapy due to its safety profile and availability without prescription (Bruggink et al., 2010). Nevertheless, treatment adherence can be a challenge, as it requires prolonged and regular application, and results may be slow to appear.

Another important pharmacological option is imiquimod, an immune response modifier that stimulates the production of cytokines, including interferon-alpha, thereby enhancing the host's antiviral immune response (Hanna et al., 2016). Imiquimod is particularly useful in the treatment of anogenital warts but has also been applied off-label for cutaneous lesions. While it offers the advantage of targeting the underlying viral infection rather than merely destroying the lesion, its use may be associated with local inflammatory reactions such as erythema, itching, and discomfort.

5-fluorouracil, a topical antimetabolite, has also been used in the treatment of recalcitrant warts. It inhibits DNA synthesis in rapidly dividing cells, including HPV-infected keratinocytes (Kwok et al., 2012). Although studies have reported moderate efficacy, its use is often limited by local irritation and the need for careful application under medical supervision.

In recent years, increasing attention has been given to immunotherapeutic approaches, particularly intralesional immunotherapy. Agents such as Candida antigen, measles–mumps–rubella vaccine, and other intralesional immunogens have been investigated for their ability to induce a systemic immune response capable of clearing both treated and distant lesions (Nofal et al., 2013; Mullen et al., 2024). This approach is especially promising for patients with multiple or treatment-resistant warts. Emerging evidence suggests that intralesional immunotherapy may offer favorable clearance rates with acceptable tolerability, although further large-scale studies are needed to confirm long-term outcomes (Mullen et al., 2024).

Systemic therapies are less commonly used but may be considered in severe or widespread cases. These include oral cimetidine and zinc supplementation, which have been proposed to enhance immune function (Kwok et al., 2012). However, the evidence supporting their effectiveness remains inconsistent, and their use is not routinely recommended in clinical guidelines.

Despite the availability of multiple pharmacological options, no single therapy has been universally accepted as superior. Treatment outcomes are often unpredictable, and recurrence remains a significant concern (Sterling et al., 2014). As a result, combination therapies—such as the use of keratolytic agents alongside immunomodulators—are frequently employed in clinical practice to improve efficacy.

Overall, pharmacological treatments play a crucial role in the management of HPV-induced warts, particularly as initial interventions. However, their limitations highlight the need for more effective and patient-friendly approaches, as well as the integration of novel therapeutic strategies and technologies discussed in subsequent sections.

3.2. Procedural and Physical Treatments

Procedural and physical treatment modalities constitute a cornerstone in the management of HPV-induced warts, particularly in cases where pharmacological therapies prove ineffective or when rapid lesion removal is desired (Sterling et al., 2014; Kwok et al., 2012). These methods are typically performed in clinical settings and aim to physically destroy infected tissue, thereby eliminating visible lesions.

Cryotherapy is one of the most commonly used procedural treatments and is widely regarded as a standard second-line therapy (Bruggink et al., 2010; Cockayne et al., 2011). This technique involves the application of liquid nitrogen to induce cellular destruction through freezing and subsequent necrosis of infected keratinocytes. Cryotherapy is relatively quick and can be performed during routine outpatient visits. Its effectiveness has been demonstrated in clinical studies, although it often requires multiple treatment sessions. Adverse effects may include pain, blistering, hypopigmentation, and, in some cases, scarring.

Laser therapy represents a more advanced approach, particularly for recalcitrant or extensive warts. Various laser types, including carbon dioxide, pulsed dye, and erbium-based systems, have been employed in clinical practice. These modalities work by selectively targeting and destroying vascular structures or tissue components associated with the wart (Iranmanesh et al., 2021). Pulsed dye laser therapy, for instance, targets hemoglobin within blood vessels supplying the wart, leading to vascular destruction and lesion regression. More recent clinical evidence has supported the effectiveness of pulsed dye laser treatment for warts on the hands and feet, while broader reviews suggest laser treatment may be particularly useful in selected resistant cases (Campolmi et al., 2023; Hekmatjah et al., 2021).

Electrosurgery and curettage are additional options that involve the physical removal of wart tissue through scraping followed by cauterization. These techniques can be effective for isolated lesions and allow for immediate removal (Sterling et al., 2014). However, they are associated with a higher risk of scarring and may not be suitable for cosmetically sensitive areas.

Photodynamic therapy has emerged as a promising alternative, particularly for resistant warts. This method involves the application of a photosensitizing agent followed by exposure to a specific wavelength of light, resulting in the generation of reactive oxygen species that selectively destroy abnormal cells. Available evidence suggests that photodynamic therapy can achieve favorable efficacy with relatively low recurrence in selected patients, although protocols vary across studies (Shen et al., 2022; Zhu et al., 2022).

Another approach includes cantharidin-based treatments, which induce blister formation beneath the wart, leading to its eventual detachment. This method is often used in pediatric populations due to its non-invasive nature and relatively low pain during application, although blistering can cause temporary discomfort (Vakharia et al., 2018).

While procedural treatments generally provide faster results compared to pharmacological therapies, they are not without limitations. Pain, cost, risk of scarring, and the need for repeated interventions remain important considerations. Moreover, these methods primarily address the physical manifestation of the infection without directly targeting the underlying viral cause, which may contribute to recurrence (Kwok et al., 2012).

In clinical practice, procedural treatments are frequently combined with pharmacological or immunotherapeutic approaches to enhance effectiveness and reduce recurrence rates (Sterling et al., 2014). The selection of an appropriate method depends on multiple factors, including lesion characteristics, patient preferences, resource availability, and clinician expertise.

Overall, procedural and physical therapies play a critical role in the comprehensive management of HPV-induced warts. However, their limitations underscore the importance of continued innovation and the integration of emerging technologies, which are discussed in the following section.

3.3. Emerging and Digital Health Technologies

In recent years, the rapid advancement of digital health technologies has significantly influenced the field of dermatology, offering innovative solutions for the diagnosis, monitoring, and management of skin conditions, including HPV-induced warts (World Health Organization, 2021; Topol, 2019). These technologies have become particularly relevant in the context of increasing demand for accessible, efficient, and patient-centered healthcare services.

Teledermatology has emerged as one of the most impactful developments in this domain. It enables remote consultation and diagnosis through the use of digital images and communication platforms, allowing patients to receive expert dermatological assessment without the need for in-person visits (Lee & English, 2018; Trettel et al., 2018). This approach has proven especially valuable in rural or underserved areas, where

access to specialized care is limited. In the context of HPV-induced warts, teledermatology facilitates early detection, follow-up monitoring, and treatment evaluation, thereby improving continuity of care and reducing delays in management (Kazi et al., 2021).

Mobile health applications also play an increasingly important role in patient engagement and self-management. Smartphone-based applications allow patients to document the progression of skin lesions, receive treatment reminders, and access educational resources. These tools can enhance adherence to long-term therapies, such as topical treatments, which often require consistent application over extended periods (Free et al., 2013). Additionally, some applications incorporate image analysis features, enabling preliminary assessment of skin lesions and prompting users to seek professional consultation when necessary.

Artificial intelligence has introduced new possibilities for automated and highly accurate analysis of dermatological images. Machine learning algorithms, particularly deep learning models, have demonstrated performance comparable to dermatologists in the classification of certain skin conditions (Esteva et al., 2017; Tschandl et al., 2020). While most existing AI systems have been developed for the detection of skin cancers, their application is expanding more broadly across dermatological triage and lesion assessment. AI-assisted tools may support clinicians by improving diagnostic accuracy, standardizing assessments, and reducing workload, especially in high-demand healthcare settings.

Another emerging area involves the integration of digital platforms with treatment delivery systems. For example, remote monitoring technologies can be combined with home-based therapeutic devices, such as over-the-counter cryotherapy kits, enabling patients to manage their condition under virtual supervision. This model aligns with the broader trend toward decentralized healthcare, where treatment is increasingly delivered outside traditional clinical environments (World Health Organization, 2021).

Despite their potential benefits, digital health technologies also present several challenges. Variability in image quality, data privacy concerns, and regulatory issues remain significant barriers to widespread adoption (Kruse et al., 2018). Moreover, disparities in digital literacy and access to technology may limit the effectiveness of these solutions in certain populations, potentially exacerbating existing health inequalities (Braveman & Gottlieb, 2014).

Nevertheless, the integration of digital health tools into dermatological practice represents a promising step toward more efficient and inclusive healthcare systems. In the management of HPV-induced warts, these technologies offer opportunities to enhance early diagnosis, improve treatment adherence, and expand access to care. As digital innovations continue to evolve, their role in dermatology is expected to grow, contributing to more personalized and accessible treatment strategies.

3.4. Comparative Synthesis of Therapeutic Approaches

When the evidence from pharmacological, procedural, and technology-enabled approaches is considered together, a recurring pattern emerges: effectiveness is shaped not only by the intrinsic properties of the intervention but also by treatment burden, recurrence risk, accessibility, and patient preference. In other words, therapeutic success in HPV-induced warts cannot be reduced to simple lesion clearance. For many patients, the most acceptable treatment is the one that balances efficacy, tolerability, cost, and feasibility over time (Sterling et al., 2014; Zhu et al., 2022).

Topical pharmacological treatments, particularly salicylic acid, remain important because they are inexpensive, widely accessible, and familiar to both clinicians and patients (Kwok et al., 2012). Their main disadvantage lies in the prolonged treatment course and the dependence on sustained adherence. In real-world practice, treatments that require daily application for several weeks may underperform because patients discontinue therapy early or apply medication inconsistently. Imiquimod and other immune-modulating therapies address some of the biological limitations of destructive treatments, but their use is constrained by irritation, cost, and variable evidence across different wart types (Hanna et al., 2016).

Procedural therapies tend to offer faster visible results, which may improve patient satisfaction in selected cases. Cryotherapy remains one of the most commonly chosen office-based treatments because it is familiar, relatively inexpensive compared with device-dependent procedures, and supported by comparative trials (Bruggink et al., 2010; Cockayne et al., 2011). However, repeated visits, pain during treatment, and the risk of pigmentary change or scarring can reduce acceptability, especially for children or for lesions in cosmetically sensitive areas. Laser therapy and photodynamic therapy may be particularly useful in recalcitrant disease, but these modalities require specialized expertise and infrastructure and are therefore less scalable across different healthcare settings (Iranmanesh et al., 2021; Shen et al., 2022).

Immunotherapeutic strategies may represent the most conceptually attractive option for recurrent or multiple warts because they aim to stimulate systemic immune clearance rather than simply removing visible tissue. This feature is important when lesions are numerous or distributed across different body sites. Nevertheless, the immunotherapy literature remains methodologically heterogeneous, with different injected agents, dosing schedules, lesion types, and outcome measures, which complicates direct comparison and routine protocol standardization (Nofal et al., 2013; Mullen et al., 2024). At present, these modalities appear promising rather than definitively established.

Digital health does not replace the above treatments, but it changes how they may be delivered, monitored, and integrated into care pathways. Teledermatology can reduce diagnostic delay, help prioritize in-person visits, and support follow-up after procedural treatment. Mobile health tools can improve adherence to self-administered therapies, while AI may in the future support triage and reduce the burden on overstretched dermatology services (Lee & English, 2018; Free et al., 2013; Tschandl et al., 2020). The comparative advantage of digital health therefore lies less in direct antiviral efficacy and more in improving healthcare delivery, continuity, and access.

Taken together, the current evidence suggests that treatment selection should follow a stratified logic. Patients with limited disease, good treatment adherence, and easy access to follow-up may benefit from low-cost topical options. Patients with painful, persistent, or functionally limiting lesions may benefit more from procedural escalation. Patients with multiple recalcitrant lesions may represent the group most likely to benefit from intralesional immunotherapy. Meanwhile, digital-health tools may add value at each stage by improving triage, documentation, adherence, and longitudinal monitoring. This integrated interpretation is consistent with the interdisciplinary focus of contemporary healthcare, in which clinical effectiveness must be considered alongside usability, scalability, and equity (World Health Organization, 2021; Maghiar et al., 2024).

4. Discussion

The management of HPV-induced warts remains a complex and evolving area within dermatology, characterized by a wide range of therapeutic options but no universally effective treatment (Sterling et al., 2014; Kwok et al., 2012). The findings of this review highlight the multifaceted nature of wart management, encompassing pharmacological, procedural, and increasingly technological approaches. Despite decades of clinical experience, the persistence and recurrence of warts continue to present significant challenges for both patients and healthcare providers.

From a clinical perspective, conventional pharmacological treatments such as salicylic acid and imiquimod remain foundational due to their accessibility, safety, and cost-effectiveness (Kwok et al., 2012; Hanna et al., 2016). However, their limitations—particularly prolonged treatment duration, variable efficacy, and reliance on patient adherence—reduce their overall effectiveness in real-world settings. Procedural interventions, including cryotherapy and laser therapy, offer more immediate results and higher clearance rates in some cases, yet they are often associated with discomfort, higher costs, and limited availability (Bruggink et al., 2010; Iranmanesh et al., 2021). Importantly, most of these approaches primarily target the visible lesion rather than the underlying viral infection, which may help explain the high recurrence observed across treatment modalities (Sterling et al., 2014).

The growing interest in immunotherapeutic strategies reflects a shift toward addressing the underlying pathophysiology of HPV infection. Intralesional immunotherapy, in particular, has demonstrated promising results by stimulating systemic immune responses capable of clearing both treated and distant lesions (Nofal et al., 2013; Mullen et al., 2024). This approach aligns with a broader trend in medicine toward therapies that modulate host immunity rather than relying solely on destructive techniques. Nevertheless, the current evidence base remains heterogeneous, and further randomized controlled trials are needed to establish standardized protocols and robust long-term outcomes.

A practical implication of the available evidence is that treatment selection should be individualized. Warts vary substantially with respect to number, anatomical location, patient age, pain, cosmetic impact, immune status, and prior treatment history. For example, a single common wart in an otherwise healthy patient may be appropriately managed with topical keratolytics and watchful follow-up, whereas multiple recalcitrant lesions in an immunocompromised patient may justify escalation to procedural therapy or intralesional immunotherapy. This individualized approach is consistent with guideline-based care, but it also reflects the reality that the wart literature rarely supports a one-size-fits-all algorithm (Sterling et al., 2014; Zhu et al., 2022).

A key contribution of this review is the integration of digital health technologies into the discussion of HPV-induced wart management. The emergence of teledermatology has significantly expanded access to dermatological care, particularly in geographically remote or resource-limited settings (Lee & English, 2018; Kazi et al., 2021). By enabling remote diagnosis and follow-up, teledermatology reduces barriers to care, shortens waiting times, and facilitates early intervention. In the context of HPV-induced warts, this is particularly relevant, as earlier assessment and management may help reduce lesion spread and treatment delay.

Similarly, mobile health applications and digital monitoring tools offer new opportunities to improve patient adherence and engagement. Long-term treatments, such as topical therapies, often fail due to inconsistent use; therefore, digital reminders, progress tracking, and educational content can play a useful role in enhancing treatment outcomes (Free et al., 2013). These tools also empower patients to take a more active role in managing their condition, which is increasingly recognized as an important component of effective healthcare delivery.

Artificial intelligence represents another transformative development with significant implications for dermatology. AI-based image analysis systems have demonstrated high levels of accuracy in the classification of skin lesions and hold potential for supporting triage and diagnostic workflows (Esteva et al., 2017; Tschandl et al., 2020). While current applications are more advanced in skin cancer recognition than in wart-specific diagnostics, the technological trajectory suggests that similar approaches could be adapted for benign lesions. However, issues related to data quality, algorithm bias, and clinical validation must be addressed before widespread implementation can be achieved (Topol, 2019).

Beyond clinical and technological considerations, the management of HPV-induced warts must also be viewed through a public health lens. Although warts are generally benign, their high prevalence and potential for transmission make them a relevant population health concern (Bruni et al., 2019; Maghiar et al., 2024). Environmental factors, such as communal facilities and hygiene practices, contribute to the spread of infection, while social determinants of health—including socioeconomic status, access to healthcare, and health literacy—affect both incidence and treatment outcomes (Braveman & Gottlieb, 2014). Addressing these broader determinants is essential for reducing disease burden and promoting equitable healthcare access.

Health inequalities represent a particularly important issue in this context. While advanced treatments such as laser therapy and digital health solutions offer significant benefits, they are not equally accessible to all populations. Individuals in low-resource settings may have limited access to both specialized dermatological care and digital technologies, potentially exacerbating existing disparities (World Health Organization, 2021). Therefore, the implementation of innovative solutions must be accompanied by strategies to ensure inclusivity and accessibility. In practice, this means designing low-bandwidth teledermatology pathways, improving digital literacy, and ensuring that patient education materials are understandable and culturally appropriate.

The psychosocial impact of HPV-induced warts is another critical aspect that warrants consideration. Despite their benign nature, warts can significantly affect patients' quality of life, particularly when located on visible areas of the body (Salah, 2018; Mohta et al., 2021). Feelings of embarrassment, social stigma, and reduced self-esteem are commonly reported, highlighting the importance of a holistic approach to treatment that addresses both physical and psychological well-being.

Overall, the findings of this review underscore the need for a multidisciplinary approach to the management of HPV-induced warts. Traditional therapies remain essential, but their limitations necessitate the integration of emerging technologies and public health strategies. Future research should focus on the development of more effective and targeted therapies, as well as the evaluation of digital health interventions in real-world settings. In particular, studies assessing the long-term impact of teledermatology, AI-assisted diagnostics, and mobile health applications on treatment outcomes and healthcare accessibility are needed.

The management of HPV-induced warts is undergoing a gradual transformation driven by technological innovation and a growing emphasis on patient-centered care. By combining clinical expertise with digital solutions and public health initiatives, it is possible to improve treatment effectiveness, enhance accessibility, and ultimately support better health outcomes and well-being.

5. Conclusions

Human papillomavirus-induced warts remain a prevalent and clinically challenging condition, characterized by variable treatment responses and frequent recurrence. This review highlights that, despite the wide range of available therapeutic options, no single modality has proven universally effective. Conventional pharmacological treatments, such as salicylic acid and imiquimod, continue to serve as first-line approaches due to their accessibility and safety profile, while procedural interventions, including cryotherapy and laser therapy, offer more rapid lesion clearance in selected cases.

However, these traditional strategies are often limited by incomplete efficacy, patient discomfort, and the inability to directly target the underlying viral infection. Emerging immunotherapeutic approaches show promise in addressing these limitations by enhancing host immune responses, although further research is required to establish their long-term effectiveness and standardization.

Importantly, the integration of digital health technologies represents a significant advancement in the management of HPV-induced warts. Teledermatology, mobile health applications, and artificial intelligence-based diagnostic tools have the potential to improve early detection, enhance treatment adherence, and expand access to care, particularly in underserved populations.

From a public health perspective, addressing the social and environmental determinants of HPV transmission and treatment accessibility is essential for reducing disease burden and promoting health equity. Additionally, the psychosocial impact of warts underscores the need for holistic management approaches that consider both physical and emotional well-being.

Future research should focus on the development of more effective, targeted therapies and the evaluation of digital health interventions in diverse clinical settings. A multidisciplinary approach that integrates clinical expertise, technological innovation, and public health strategies will be crucial for improving outcomes in patients affected by HPV-induced warts.

REFERENCES

1. Braveman, P., & Gottlieb, L. (2014). The social determinants of health: It's time to consider the causes of the causes. *Public Health Reports, 129*(Suppl. 2), 19–31. https://doi.org/10.1177/00333549141291S206
2. Bruggink, S. C., Gussekloo, J., de Koning, M. N. C., Egberts, P. F., ter Schegget, J., Feltkamp, M. C. W., Bavinck, J. N. B., & Assendelft, W. J. J. (2010). Cryotherapy with liquid nitrogen versus topical salicylic acid application for cutaneous warts in primary care: Randomized controlled trial. *CMAJ, 182*(15), 1624–1630. https://doi.org/10.1503/cmaj.092194
3. Bruni, L., Albero, G., Serrano, B., Mena, M., Collado, J. J., Gómez, D., Muñoz, J., Bosch, F. X., & de Sanjosé, S. (2019). Global epidemiology of human papillomavirus infection. *The Lancet Global Health, 7*(5), e596–e603. https://doi.org/10.1016/S2214-109X(19)30082-0
4. Campolmi, P., Quintarelli, L., Fusco, I., Ronconi, L., Troiano, M., Cannarozzo, G., & Lotti, T. (2023). Clinical evidence of 595 nm pulse dye laser treatment for viral warts on hands and feet. *Skin Research and Technology, 29*(9), e13460. https://doi.org/10.1111/srt.13460
5. Cockayne, S., Hewitt, C., Hicks, K., Jayakody, S., Kang'ombe, A. R., Stamuli, E., Turner, D., Thomas, K., & Lamb, S. E. (2011). Cryotherapy versus salicylic acid for the treatment of plantar warts (verrucae): A randomised controlled trial. *BMJ, 342*, d3271. https://doi.org/10.1136/bmj.d3271
6. Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *Nature, 542*(7639), 115–118. https://doi.org/10.1038/nature21056
7. Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., Patel, V., & Haines, A. (2013). The effectiveness of mobile-health technologies to improve health care service delivery processes: A systematic review and meta-analysis. *PLoS Medicine, 10*(1), e1001362. https://doi.org/10.1371/journal.pmed.1001363
8. Hanna, E., Abadi, R., & Abbas, O. (2016). Imiquimod in dermatology: An overview. *International Journal of Dermatology, 55*(8), 831–844. https://doi.org/10.1111/ijd.13235
9. Hekmatjah, J., Farshchian, M., Grant-Kels, J. M., & Mehregan, D. (2021). The status of treatment for plantar warts in 2021: No definitive advancements in decades for a common dermatology disease. *Clinics in Dermatology, 39*(4), 688–694. https://doi.org/10.1016/j.clindermatol.2021.05.024
10. Iranmanesh, B., Khalili, M., Zartab, H., Amiri, R., & Aflatoonian, M. (2021). Laser therapy in cutaneous and genital warts: A review article. *Dermatologic Therapy, 34*(1), e14671. https://doi.org/10.1111/dth.14671
11. Kazi, R., Evankovich, M. R., Liu, R., Liu, A., Moorhead, A., Ferris, L. K., Falo, L. D., & English, J. C. (2021). Utilization of asynchronous and synchronous teledermatology in a large health care system during the COVID-19 pandemic. *Telemedicine and e-Health, 27*(7), 771–777. https://doi.org/10.1089/tmj.2020.0299

12. Kruse, C. S., Karem, P., Shifflett, K., Vegi, L., Ravi, K., & Brooks, M. (2018). Evaluating barriers to adopting telemedicine worldwide: A systematic review. *Journal of Telemedicine and Telecare, 24*(1), 4–12. https://doi.org/10.1177/1357633X16674087
13. Kwok, C. S., Gibbs, S., Bennett, C., Holland, R., & Abbott, R. (2012). Topical treatments for cutaneous warts. *Cochrane Database of Systematic Reviews, 2012*(9), CD001781. https://doi.org/10.1002/14651858.CD001781.pub3
14. Lee, J. J., & English, J. C. (2018). Teledermatology: A review and update. *American Journal of Clinical Dermatology, 19*(2), 253–260. https://doi.org/10.1007/s40257-017-0317-6
15. Maghiar, L., Sandor, M., Sachelarie, L., Bodog, R., & Huniadi, A. (2024). Skin lesions caused by HPV—A comprehensive review. *Biomedicines, 12*(9), 2098. https://doi.org/10.3390/biomedicines12092098
16. Mohta, A., Jain, S. K., Kushwaha, R. K. S., Singh, A., Gautam, U., & Nyati, A. (2021). Estimating the impact of extragenital warts versus genital warts on quality of life in immunocompetent Indian adult patients: A comparative cross-sectional study. *Indian Journal of Dermatology, 66*(1), 44–50. https://doi.org/10.4103/ijd.IJD_290_19
17. Mullen, S. A., Ghouse, S. M., Daveluy, S., Schrom, K., & Shi, V. Y. (2024). Systematic review of intralesional therapies for cutaneous warts. *JAAD International, 14*, 91–101. https://doi.org/10.1016/j.xjidi.2024.100264
18. Nofal, A., Salah, E., Nofal, E., & Yosef, A. (2013). Intralesional antigen immunotherapy for the treatment of warts: Current concepts and future prospects. *American Journal of Clinical Dermatology, 14*(4), 253–260. https://doi.org/10.1007/s40257-013-0018-8
19. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71
20. Salah, E. (2018). Impact of multiple extragenital warts on quality of life in immune-competent Egyptian adults: A comparative cross-sectional study. *Clinical, Cosmetic and Investigational Dermatology, 11*, 289–295. https://doi.org/10.2147/CCID.S165908
21. Shen, S., Ni, X., Zhao, Y., Zhang, L., Wang, Y., & Liu, J. (2022). Efficacy of photodynamic therapy for warts induced by human papillomavirus infection: A systematic review and meta-analysis. *Photodiagnosis and Photodynamic Therapy, 38*, 102832. https://doi.org/10.1016/j.pdpdt.2022.102913
22. Stanley, M. (2012). Immunobiology of HPV infection. *Vaccine, 30*(Suppl. 5), F83–F87. https://doi.org/10.1016/j.vaccine.2012.05.016
23. Sterling, J. C., Gibbs, S., Haque Hussain, S. S., Mohd Mustapa, M. F., & Handfield-Jones, S. E. (2014). British Association of Dermatologists' guidelines for the management of cutaneous warts 2014. *British Journal of Dermatology, 171*(4), 696–712. https://doi.org/10.1111/bjd.13310
24. Topol, E. J. (2019). High-performance medicine: The convergence of human and artificial intelligence. *Nature Medicine, 25*(1), 44–56. https://doi.org/10.1038/s41591-018-0300-7
25. Trettel, A., Eissing, L., & Augustin, M. (2018). Telemedicine in dermatology: Findings and experiences worldwide—A systematic literature review. *Journal of the European Academy of Dermatology and Venereology, 32*(2), 215–224. https://doi.org/10.1111/jdv.14341
26. Tschandl, P., Rinner, C., Apalla, Z., Argenziano, G., Codella, N., Halpern, A., Janda, M., Lallas, A., Longo, C., Malvehy, J., Paoli, J., Puig, S., Sinz, C., Soyer, H. P., & Kittler, H. (2020). Human–computer collaboration for skin cancer recognition. *Nature Medicine, 26*(8), 1229–1234. https://doi.org/10.1038/s41591-020-0942-0
27. Vakharia, P. P., Chopra, R., Silverberg, N. B., & Silverberg, J. I. (2018). Efficacy and safety of topical cantharidin treatment for molluscum contagiosum and warts: A systematic review. *American Journal of Clinical Dermatology, 19*(6), 791–803. https://doi.org/10.1007/s40257-018-0375-4
28. World Health Organization. (2021). *Global strategy on digital health 2020–2025*. World Health Organization.
29. Zhu, P., Qi, R. Q., Yang, Y., Zhang, L., Wang, Y., & Liu, J. (2022). Clinical guideline for the diagnosis and treatment of cutaneous warts (2022). *Journal of Evidence-Based Medicine, 15*(3), 284–301. https://doi.org/10.1111/jebm.12494