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INTEGRATION OF TELEDERMATOLOGY INTO CLINICAL PRACTICE: DIAGNOSTIC RELIABILITY AND PATIENT OUTCOMES

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Abstract

The provision of dermatological care via electronic communication technologies, known as teledermatology, is an important component of modern healthcare systems, especially in low- and middle-income countries (LMICs) where dermatological disease burden is high, and expertise in dermatology and other skin conditions is scarce. This review assesses the current evidence of teledermatology regarding diagnostic accuracy, patient outcomes, challenges to implementation, and the possible role of teledermatology in South Asian countries particularly in Pakistan. PubMed, Scopus, EMBASE and Google Scholar were searched for studies published from 2005 to 2025, yielding a systematic review of studies that were reviewed. A systematic review of studies from PubMed, Scopus, EMBASE and Google Scholar identified that store-and-forward (SAF) teledermatology achieves diagnostic concordance rates between 70-91% when compared with face-to-face consultations and that real-time video consultations are equally effective. Teledermatology lowers wait time, lowers the number of unnecessary referrals by 40-55% and has a patient satisfaction rate of more than 82%. AI Teledermatology is also promising in the field of lesion triage and diagnosis. There is still a lack of long-term outcome data and LMIC-specific research. Pakistan has a high prevalence of mobile phone usage, limited number of dermatologists and a high burden of skin diseases, which augur well for the adoption of teledermatology. Overall, teledermatology is a viable and cost-effective solution that can be used to enhance access to dermatological services where supported by the right policy, training and regulatory measures.

1. INTRODUCTION

Dermatological conditions are the most visible, common and socially significant diseases encountered in practice. The latest Global Burden of Disease estimate found that more than 900 million people suffer from a dermatological condition at any given time, with the group of dermatological diseases collectively ranking as the fourth leading cause of non fatal disability globally (Hay et al., 2014). However, this high burden of disease is associated with an unequal distribution of dermatological expertise. In developed economies waiting times for dermatology outpatients are commonly in excess of two months; in low and middle income countries (LMICs) dermatological expertise is often lacking in whole sub regions (Karimkhani et al., 2017).

Teledermatology the use of electronic information and communication technologies to provide remote dermatological assessment and management has been a highly promising solution to this problem. The idea is not new; first descriptions of image-based teledermatology appeared in the mid 1990s, when Esteva and colleagues showed that digitised clinical images transmitted over an early internet network could inform clinical decision making. (Leal-Costa et al., 2022) What has changed radically in the intervening three decades is the technology landscape: smartphones with cameras capable of 200 megapixel resolution, handheld dermatoscopes costing less than USD 100, high

speed and 4G mobile networks covering previously inaccessible regions, and artificial intelligence algorithms able to diagnose skin lesions with accuracy that matches expert dermatologists have all opened new horizons for teledermatology (Esteva et al., 2017).

The COVID 19 pandemic in 2020-2022 accelerated what may have been a ten year transition into a period of just 18 months. Dermatology departments around the world saw a greater than 1,000% increase in teledermatology consultations compared with the previous year as pandemic restrictions, shielding and overwhelmed health systems led to the rapid repurposing of pathways. Many of the emergency regulatory approvals and reimbursement mechanisms that were put in place at that time have now become standard, and the clinical community has largely adopted teledermatology as a permanent and important part of dermatological practice (Mahmood et al., 2022).

While teledermatology has great potential, it also presents clinical and ethical challenges. For example, in suspected melanoma, the accuracy of diagnosis shows considerable variability in studies, and misclassification is possible, especially when the lesions are malignant, as it may affect timely treatment. Systematic reviews reveal that although teledermatology often performs well with high levels of concordance, it's not always comparable to in person dermatology, particularly in complex and risky lesions. Also, studies indicate ongoing disparities in diagnostic accuracy between groups, suggesting that digital health technologies could potentially perpetuate or worsen digital health inequalities. These issues are especially pertinent in resource limited contexts, like Pakistan, where there is a severe shortage of specialists, with a need to consider the way in which teledermatology is delivered to ensure safe and equitable access to care. The aim of this narrative review is to answer these questions in a rigorous and specific manner. It reviews the global evidence on the diagnostic accuracy and patient outcomes of teledermatology, explores structural factors that may hinder or support teledermatology integration into clinical practice and, most importantly, addresses a largely overlooked area of teledermatology. its potential and practical feasibility in the South Asian healthcare context. It will therefore serve both the academic community as a review of the literature and the clinical, policy and health system planning community in Pakistan and other countries as a practical guide (Liu et al., 2020; Butt et al., 2021)

2. BACKGROUND AND EPIDEMIOLOGY

2.1 Global Burden of Skin Disease

Skin diseases are globally the fourth greatest cause of non-fatal disease burden as measured by years lived with disability (YLDs) - at around 40 million YLDs per year (Hay and Kofoed). Dermatitis, fungal infections, acne vulgaris, psoriasis and urticaria are the most common, causing significant morbidity across all ages and socioeconomic groups. Skin cancers, including melanoma and non melanoma skin cancers (NMSCs) such as basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) are the most prevalent cancers in fair skinned people, with 1.5 million new cases of melanoma and keratinocyte carcinomas diagnosed worldwide annually (Finnane et al., 2017).

The burden of neglected tropical skin diseases (NTSDs) such as cutaneous leishmaniasis, leprosy, Buruli ulcer and tungiasis adds a further layer of burden, disproportionately affecting the LMICs where they occur, and often in populations marginalised by poverty and geographical isolation (Joshi and Ren, 2021). The overall impact is one of unmet need on a grand scale, compounded by the unequal global distribution of dermatologists: the World Health Organization estimates that at least 300,000 dermatologists are needed worldwide, with the deficit overwhelmingly in Africa and South Asia.

2.2 The Dermatologist Workforce Crisis

The dermatologist deficit is not just a deficit of education capability; it's also a deficit of geography. Even in countries with a relatively sufficient number of dermatologists, the geographic distribution of dermatologists in urban tertiary centres results in access deserts in rural and peri urban regions. In the United Kingdom, for example, median waiting times for routine dermatology outpatients appointments are greater than 12 weeks in a number of National Health Service (NHS) trusts despite more than 1,000 consultant dermatologists in practice. In the US, less than 30% of the per capita dermatologists practising in metropolitan

areas work in rural counties (Kimball and Resneck, 2008;Lee, 2018).

In Pakistan the problem is more severe. With an estimated 400-600 practising dermatologists for a population of more than 230 million people (a ratio of 1: 400,000) and a preponderance of dermatologists found in the three metropolitan centres of Lahore, Karachi and Islamabad, routine access to dermatologists is effectively absent for the rural and semi urban population (Rashid and Hussain, 2005). This infrastructure gap is compounded by the burden of skin disease including cutaneous leishmaniasis (endemic to Balochistan, Khyber Pakhtunkhwa and parts of Sindh), leprosy, widespread fungal infections in hot, humid environments and an emerging burden of skin cancers among outdoor farmworkers, which are largely undiagnosed and untreated (Janjua, Hussain, Bari, Ammad, & Naz, 2011).

2.3 The Rise of Digital Health and Teledermatology

According to Pakistan telecommunication authority the global expansion of mobile connectivity has created unprecedented infrastructure for digital health delivery. By 2024, mobile phone penetration exceeded 65% globally and surpassed 84% in Pakistan a country where broadband fixed line infrastructure remains limited but mobile 3G/4G networks have expanded substantially over the past decade. This mobile-first digital landscape is particularly consequential for teledermatology, which can in principle operate with little more than a smartphone camera, a secure messaging platform, and a trained clinician at the receiving end. (Naik, 2022; Dofitas & Villena).

Teledermatology platforms have diversified substantially from their early iterations. The dominant modalities described in detail in section 3 now encompass asynchronous store and forward (SAF) systems, synchronous video consultations, hybrid approaches, patient initiated mobile health (mHealth) applications, and AI augmented diagnostic tools. Each modality carries a distinct combination of technical requirements, workflow implications, and clinical applicability that must be understood in the context of specific healthcare system characteristics (Sivamani, 2023).

3. TELEDERMATOLOGY MODALITIES: CLASSIFICATION AND MECHANISMS

3.1 Classification of Modalities

To understand teledermatology, it is important to know its operational spectrum. There are five main modalities, which vary in their technical, clinical and practice aspects. These are outlined in Table 1 and outlined below.

Table 1: Classification of Teledermatology Modalities: Technical Characteristics and Clinical Applications

Modality	Mode	Latency	Image Type	Key Clinical Use
Store-and-Forward (SAF)	Asynchronous	Hours–days	Static photos + dermoscopy	Triage, pigmented lesion review, rural outreach
Live Video (Synchronous)	Real-time	Immediate	Video stream	Complex counselling, urgent review, follow-up consultations
Hybrid (SAF + Live)	Both	Variable	Static + video	Stepwise triage then interactive discussion; academic centres
mHealth / App-based	Patient-initiated	Variable	Smartphone camera	Direct-to-consumer, self-monitoring of chronic conditions
AI-assisted Teledermatology	Automated analysis	Near-instant	Dermoscopic / clinical images	Melanoma screening, lesion pre-classification, decision support

3.2 Store-and-Forward (SAF) Teledermatology

SAF teledermatology is the most widely studied and implemented type of teledermatology globally. In SAF teledermatology, the referring clinician (usually a GP, nurse, or community health worker) takes static digital photographs of the skin lesion and enters a structured history, which is submitted to a secure server for asynchronous review by a distant dermatologist. (Jiang et al., 2022) The consulting dermatologist reviews the case at leisure (usually between 24 72 hours later) and renders a written management plan, differential diagnosis, and suggestions for review or referral for in person assessment. (Whited et al., 2004)

The major strengths of SAF are scalability a dermatologist can review a much larger volume of referrals than can be seen in a face to face clinic its asynchronous nature, and low bandwidth demands compared to synchronous video conferencing. SAF is an ideal system for triage purposes, in which dermatologists can prioritise cases according to urgency and complexity prior to allocating an in person appointment. Its main potential shortcoming is a lack of dynamic information in the two dimensional images submitted, which may not fully convey texture, three-dimensionality and lesion size. (Nelson et al., 2016)

Store and forward teledermatology enhances access to skin care in rural settings by enabling primary care providers to remotely diagnose patients and eliminate the need to travel and miss appointments. Providers consider it effective and beneficial generally, although its application is hampered by the lack of knowledge, wrong impressions, and the amount of time to complete consultations. There is support of good diagnostic accuracy with improved image quality. This can be simplified and enhanced through training, thereby boosting its uptake and making it a feasible measure to serve underserved communities. (Morrissette et al., 2022)

3.3 Synchronous Video Teledermatology

Video consultation is the closest to an in person encounter. Simultaneous interaction between clinician and patient using a secure video platform allows dynamic examination of the skin with patient repostioning for optimal lighting, zooming in to areas of interest as well as real-time history taking and counselling. (Armstrong et al., 2019) Research has shown that real-time video has equivalent diagnostic agreement with in-person consultation to SAF for the majority of inflammatory or infectious skin diseases, with added real-time clarifying information.

Synchronous teledermatology was the preferred mode during the COVID 19 pandemic, when rapid roll-out of commercial video platforms including dedicated medical platforms compliant with local privacy laws occurred in many health systems. Limitations include the need for clinician and patient to be simultaneously available, possible connectivity issues and lack of direct dermoscopy unless the patient has access to a connected handheld device. (Santiago & Lu, 2023)

3.4 Hybrid and AI-Augmented Models

Hybrid models are increasingly being introduced by health systems, which include SAF triage with synchronous follow up for complicated cases, or AI based triage of patient submitted images to identify high risk lesions for urgent human review. The use of AI in teledermatology is important to discuss given its rapid development and likely revolutionising impact, and is therefore covered in section 5 below. The pictures illustrates an overview of an integrated teledermatology pathway (Julie, Reynolds, Olbricht, & McGee, 2021)

An AI-enhanced hybrid teaching model was provided during the COVID 19 pandemic to sustain dermatology residency training through the introduction of digital tools (WhatsApp and Zoom) alongside structured academic activities. The plan shifted towards complete online education to a mixed model that incorporates virtual and in person classes, so as not to break the flow of theoretical knowledge, clinical skills, and professional growth. The assessments were based on MCQs, case discussion, review of clinical slides, mock viva, and practical workshops, with digital platforms supporting the real-time interaction and feedback. This flexible model was a viable and affordable and flexible alternative to conventional instruction especially in resource.

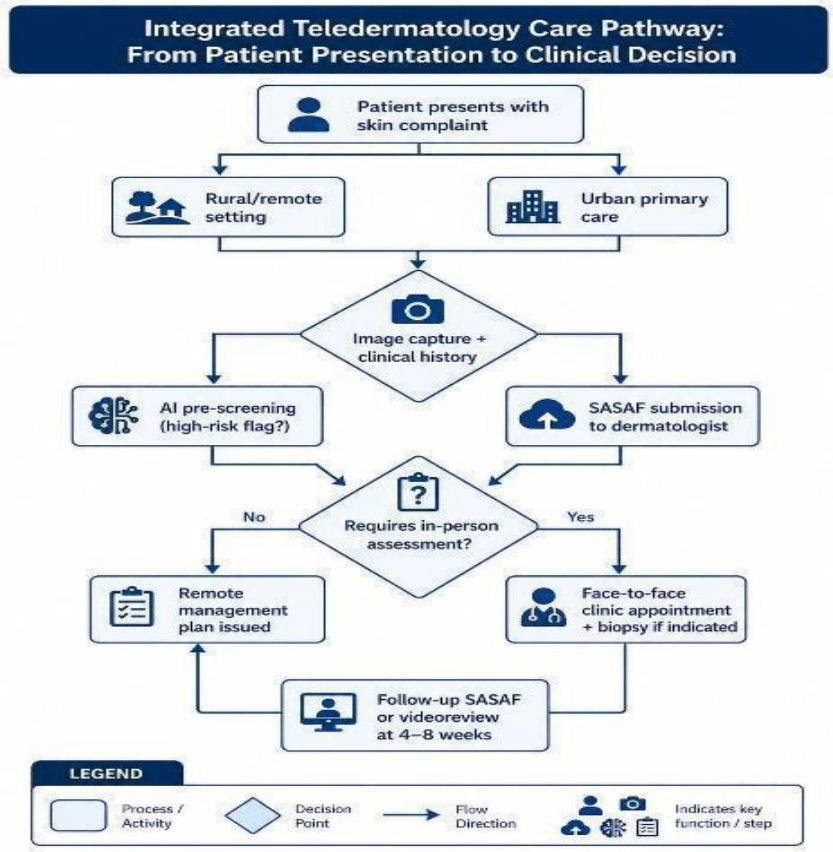

Figure 1: **Integrated Teledermatology Care Pathway: From Patient Presentation to Clinical Decision**

4. DIAGNOSTIC RELIABILITY: CURRENT EVIDENCE

4.1 Methodological Note on Concordance Studies

The literature supporting the diagnostic accuracy of teledermatology is based largely on concordance studies, which assess agreement between diagnoses made using teledermatology and a reference standard (usually face to face examination by a dermatologist, histopathology, or a panel of experts). This literature has a number of methodological variations: studies report different measures of concordance (diagnosis, diagnostic category, or management plan), secondary versus primary care settings, varying degrees of standardisation in image acquisition, and variable clinical experience of the submitting and consulting dermatologist. These variations pose challenges in pooling the results of different studies and are not always properly recognised in reviews (Krupinski et al., 2008).

4.2 Inflammatory and Common Dermatoses

Store and forward teledermatology has high diagnostic agreement with a dermatologist's face to face examination for the diagnosis of common inflammatory dermatoses including psoriasis, atopic dermatitis, contact dermatitis, rosacea and seborrhoeic dermatitis, with reported concordance rates ranging from around 70% to greater than 85% in several studies and systematic reviews. These conditions have distinctive morphological features that are captured well in digital images, contributing to the high concordance rates. Warshaw and colleagues in their landmark Veterans Affairs study reported exact diagnostic agreement for a series of 260 teledermatology consultations for a variety of common dermatoses of 76 83%, and 90% if agreement within diagnostic categories was accepted (Warshaw et al., 2011).

Contact dermatitis is an important exception. The diagnosis of contact dermatitis requires not only an appreciation of the clinical morphology but a thorough and structured history of exposure occupational, household and topical product history which in SAF teledermatology is limited by the design of the electronic referral form. Teledermatology studies for contact dermatitis show lower levels of agreement (65-78%) than those for inflammatory dermatoses with more

characteristic morphology, and highlights the need for careful consideration of the referral form design in the SAF system (Jones & Oakley, 2023).

4.3 Pigmented Lesions and Skin Cancer Triage

Pigmented lesion analysis is both the most high stakes and most widely researched use case for teledermatology. Given the implications of a missed melanoma diagnosis in terms of advanced stage disease, increased morbidity and decreased survival rates, the accuracy of melanoma diagnosis is a safety issue, rather than simply a performance issue. Traditional melanoma diagnosis is made using dermoscopy, an optical magnification device with or without polarised light that is much more accurate than visual inspection when performed by an experienced dermatologist (Moreno-Ramirez et al., 2005). Teledermatoscopy the remote assessment of dermoscopic images has been subject to several prospective studies and systematic reviews. The systematic review by Pala and colleague demonstrated that teledermatoscopy had a sensitivity for melanoma diagnosis of 80-96% and specificity of 85-95%, comparable to in person dermoscopy in most studies. The most important finding was that teledermatology triage of pigmented lesion referrals significantly reduced the proportion of benign lesions excised and expedited diagnosis of potentially serious cases a "win-win quality improvement" (Pala, Bergler-Czop, & Gwiżdż, 2020).

Tschandl and colleagues' 2019 landmark paper in The Lancet Oncology expanded on these findings to show that an artificial intelligence convolutional neural network (CNN) achieved an area under the receiver operating characteristic curve (AUC) of 0.91 for the detection of melanoma versus benign naevus, outperforming six of eleven dermatologists. These results have important implications for AI-powered teledermatology triage (Tschandl et al., 2019).

4.4 Infections, Infestations, and Neglected Tropical Skin Diseases

Infectious and infestations bacterial (cellulitis, impetigo), viral (herpes zoster, molluscum contagiosum), fungal (tinea corporis, tinea versicolor, onychomycosis) and parasitic (scabies, cutaneous leishmaniasis) are a key teledermatology use case in LMICs where these are highly prevalent and diagnostic expertise is scarce (Hay & Kofoed).

Teledermatology is highly accurate (around 70-85%) for clinically distinct and readily photographed lesions but is less accurate for less distinct lesions that require laboratory tests for confirmation, although it does still improve management and triage. Teledermatology has a high overall diagnostic agreement (about 70-85%), but is less accurate when dealing with diagnoses that require subtle clinical evaluation or laboratory testing, such as scabies and early cutaneous leishmaniasis (Warshaw et al., 2009; Heffner, Lyon, Brousseau, Holland, & Yen, 2009).

Weinberg, J., Kaddu, S., Gabler, G., & Kovarik, C. (2009), report the African Teledermatology Project, a store and forward telemedicine system linking Sub-Saharan African doctors with overseas experts in dermatology. It facilitated better diagnosis and management of skin disorders, and offered education, with frequent conditions being infections, dermatitis, psoriasis and HIV dermatoses, improving access to care in resource-poor environments (Weinberg, Kaddu, Gabler, & Kovarik, 2009).

4.5 Paediatric and Elderly Populations

Teledermatology for children is associated with some unique challenges full body photographs are often required to capture conditions common in children, lesions can change rapidly and information provided by parents may not be as accurate as adult self-reports. However, studies of paediatric teledermatology have demonstrated acceptable concordance for common childhood dermatoses viral exanthems, atopic dermatitis, impetigo, molluscum contagiosum with high parental satisfaction and considerable time and cost savings in avoiding the need to travel to the specialist centre (Coates, Kvedar, & Granstein, 2015).

Teledermatology services in the elderly are also effective, where the burden of certain common conditions venous ulcers, pressure sores, onychomycosis, drug eruptions is high in nursing homes and residential aged care facilities, and specialist input can be delivered without the physical and logistical barriers of patient transport. (Zelickson & Homan, 1997).

Teledermatology is a promising tool in delivering distant dermatologic care, and it can also assist in

overcoming the obstacles of distance, cost, and lack of availability of specialists. It helps in proper diagnosis, early management and also minimizes unnecessary face to face meetings; hence, it is cost-effective and efficient. Although the majority of evidence is grounded on adults, its applications in children gain importance because of the high impact of childhood skin diseases and lack of expertise. The common conditions treated are eczema, infections, acne and pigmentary disorders. Despite very good diagnostic agreement, there is variability, and limited research on pediatrics is available. Issues of patient doctor relationship, follow up, and reimbursement issues are some of these challenges. Generally, teledermatology is useful to both parties, but additional research is required to streamline its application in childhood medicine (Naka, Makkar, & Lu, 2017).

Table 2: Summary of Key Teledermatology Studies: Design, Findings, and Evidence Quality

Study (Author, Year)	Country	n	Modality	Concordance (%)	Key Finding
Warshaw et al., 2009	USA	260	SAF	76–83%	Strong agreement for inflammatory dermatoses; weaker for rare conditions
Finnane et al., 2017	Australia	Meta-analysis	SAF + Video	70–91%	Skin cancer triage; concordance highest for BCC and SCC using SAF + dermoscopy
Tschandl et al., 2019	International	804 images	AI (CNN)	91% (AUC)	AI outperformed 6 of 11 dermatologists on pigmented lesion classification
Armstrong et al., 2011	USA	94	Video	~80%	Patient outcomes comparable at 6 months; high satisfaction with video consult
van der Heijden et al., 2011	Netherlands	1,022	SAF (GP-initiated)	74%	52% of referrals managed fully remotely; significant cost reduction versus in-person
Snoswell et al., 2018	Australia	Systematic review	SAF	N/A	Cost-effectiveness confirmed; AU$137–$640 saved per episode versus conventional pathway
Mosam & Todd, 2016	South Africa	Narrative review	SAF (mobile)	~72%	Teledermatology effective for HIV-associated dermatoses

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in sub-Saharan LMIC context.

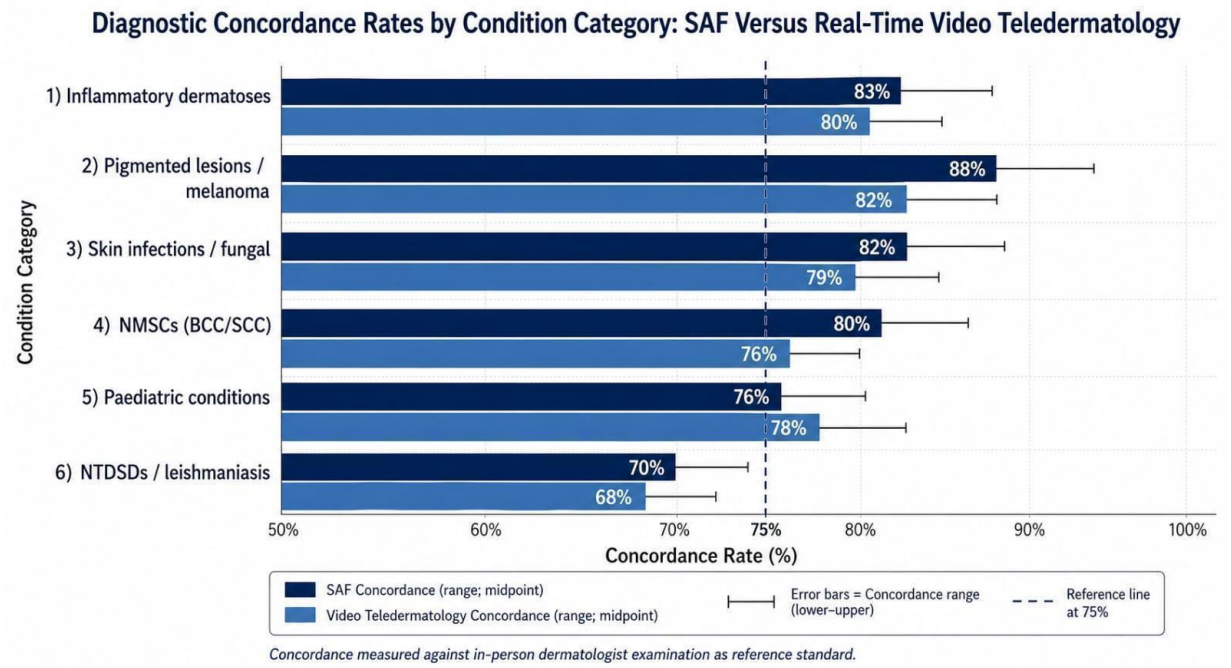

Figure 2: Diagnostic Concordance Rates by Condition Category: SAF Versus Real-Time Video Teledermatology

5. ARTIFICIAL INTELLIGENCE IN TELEDERMATOLOGY: THE EMERGING FRONTIER

5.1 Machine Learning Approaches to Skin Disease Classification

The combination of artificial intelligence and teledermatology represents what this review considers to be the "most critically understudied" aspect of teledermatology, especially in LMIC and South Asian settings. Machine learning approaches, primarily convolutional neural networks (CNNs) trained on large sets of dermoscopic images have achieved remarkable performance in experimental studies.4 The pioneering work by Chowdhury and colleagues in Nature (2017) showed that a CNN trained on 129,450 clinical images classified keratinocyte carcinomas and melanoma versus benign lesions with accuracy comparable to 21 board certified dermatologists. Most subsequent independent replication studies and direct comparisons with dermatologists of varying levels of experience have generally confirmed that AI classification, especially of dermoscopic images of common skin conditions, is comparable to experts. (Chowdhury & Last, 2025).

However, most AI teledermatology studies have used carefully curated, optimal quality dermoscopic images obtained under highly controlled conditions. In practice, teledermatology image quality, especially in primary care and patient submitted images, is more heterogeneous and AI algorithm accuracy drops with poor image quality. Training datasets for AI have been largely derived from patients with Fitzpatrick skin phototypes I III (lighter skinned patients) with a paucity of darker skin types. This skew has been shown to result in decreased AI sensitivity for the diagnosis of melanoma in patients with Fitzpatrick IV VI skin types a finding with potentially significant implications for population health equity in South Asia, sub-Saharan Africa and the Middle East (Daneshjou, Smith, Sun, Rotemberg, & Zou, 2021).

5.2 AI as Clinical Decision Support

The most justifiable and useful application for AI in teledermatology is as a clinical decision support system rather than an independent diagnostic authority. In this role, AI can play several roles: image triage to prioritise lesions for early review by a dermatologist, identify potentially cancerous lesions that a less experienced referring clinician might regard as benign, suggest differential diagnoses to broaden the clinical differential and mitigate inter clinician diagnostic variability in high volume triage centres (Fernandez, Young, Bhattarcharya, Kusari, & Wei, 2023).

Li et al, and colleagues' critical review of the methodology of published AI dermatology algorithms identified the ongoing lack of AI algorithm transparency and representativeness in the published literature, noting less than 10% of reviewed algorithms reported performance stratified by skin phototype. This lack of transparency is a major research and regulatory gap that must be addressed before AI enhanced teledermatology can be safely deployed at scale, especially in contexts with significant representation of darker skin phototypes (Li et al., 2021).

5.3 Regulatory Landscape for AI Teledermatology Tools

Dermatological AI medical devices face a range of regulatory frameworks globally. Within the European Union, AI diagnostic tools are regulated as medical devices under the Medical Device Regulation (MDR 2017/745) and are subject to the forthcoming EU AI Act, which has risk based requirements. In the United States, the Food and Drug Administration (FDA) has developed a flexible regulatory approach for AI/ML-based software as a medical device. In Pakistan and most South Asian countries, there is no specific regulatory framework for AI diagnostic tools as of 2024, leading to regulatory uncertainty for developers and potential safety concerns for consumers. (Gerke, Minssen, & Cohen, 2020).

Ethical considerations for AI in teledermatology go beyond regulatory matters. Liability in the event of a missed or delayed diagnosis when AI has recommended a diagnosis; the appropriate level of transparency regarding how the algorithm works when securing patient consent for AI based assessment; and the potential for AI based diagnosis to reinforce and widen clinical inequalities all require ongoing research and policy development (Chikhaoui, Alajmi, & Larabi-Marie-Sainte, 2022).

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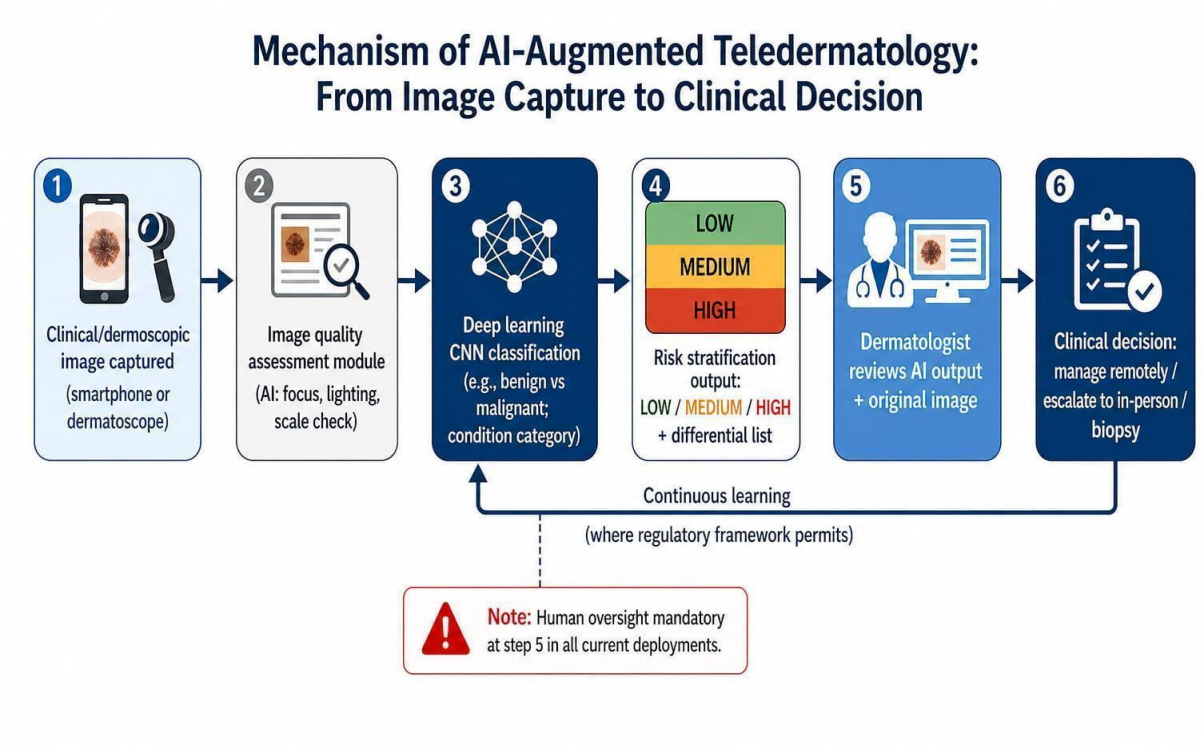

Figure 3: Mechanism of AI-Augmented Teledermatology: From Image Capture to Clinical Decision

6. PATIENT OUTCOMES: WHAT DOES THE EVIDENCE SHOW?

6.1 Access and Time-to-Assessment

The most well established effect of teledermatology on patient outcomes is that it cuts down the time to specialist assessment following GP referral. The study by Wang and co workers, a large prospective study in the Netherlands, one of the highest quality real world studies in the field, found that SAF teledermatology triage reduced median time to specialist advice from 84 days to fewer than 3 days (a reduction greater than 96%) and also enabled 52% of referrals to be entirely managed without any face-to-face contact.25 This result has been replicated in other settings and represents a clinically relevant improvement in the quality of care for patients with conditions like suspected skin cancer where delay in diagnosis has important survival implications. (Wang et al., 2020)

The benefit for access improvement is enhanced in remote and disadvantaged populations. Australian teledermatology studies have reported a reduction in patient travel burden of more than 400 kilometres per consultation in rural and remote settings, with a corresponding reduction in patient costs that exceed the cost of infrastructure investment in delivering the program. (Snoswell, Caffery, Whitty, Soyer, & Gordon, 2018) For nursing home residents, where older age or mobility impairment may have prevented attendance at a conventional consultation, teledermatology has enabled specialist input that would otherwise have been unavailable, leading to a diagnosis including malignancies that would have otherwise gone unrecognised. (E. A. Krupinski, Engstrom, Barker, Levine, & Weinstein, 2004)

6.2 Clinical Outcomes and Treatment Efficacy

Beyond measures of access, the more important question of equivalence of outcomes for patients managed via teledermatology compared to traditional face to face care has been addressed by fewer, but higher quality studies. The Lamel randomised trial (one of two RCTs on this topic) found no differences in clinical outcomes (at six-month follow up) between patients with inflammatory dermatoses receiving video teledermatology care or conventional in person care, including measures of disease severity and patient-reported outcomes. Cohort studies have reported similar findings for psoriasis, atopic dermatitis and acne managed through SAF pathways (Lamel, Chambers, Ratnarathorn, & Armstrong, 2012).

Time to surgery is an important outcome measure for skin cancer pathways. Most studies of teledermatology triage have shown that prioritisation of high-risk pigmented lesion referrals corresponds to shorter time to biopsy and definitive diagnosis (histology) versus undifferentiate dreferral queues, with some studies finding earlier stage diagnosis in teledermatology-triaged melanomas a finding with clear survival implications (Chuchu et al., 1996).

6.3 Patient Satisfaction

Several studies have assessed patient satisfaction with teledermatology across different health care settings, finding consistently high levels of satisfaction with greater than 80% of patients satisfied or very satisfied across different modalities and patient cohorts. Aspects of teledermatology with consistently high patient satisfaction include convenience of not having to travel, shorter waiting time and the opportunity to conduct a consultation in a comfortable familiar environment. Aspects with lower satisfactory ratings include the perceived lack of "persona" in remote consultations, concerns about the adequacy of remote physical examination, and technical glitches (Bowns, Collins, Walters, & McDonagh, 2006).

Crucially, teledermatology satisfaction ratings among older adults and those less familiar with digital technology are lower than among younger or more tech savvy patient populations, reflecting the digital equity aspect of teledermatology deployment. This finding highlights the need for hybrid models that continue to offer in person services as an alternative for patients unable or unwilling to use digital health platforms (Hadeler, Gitlow, & Nouri, 2021).

6.4 Cost-Effectiveness

Teledermatology cost-effectiveness has been formally assessed in systematic reviews and individual economic studies, with generally positive results. The largest economic analysis to

date, a systematic review by Snoswell and co workers, consistently demonstrated cost reductions of AU$137 to AU$640 per episode compared with traditional pathways, based on avoidance of unnecessary face-to-face specialist consultations, avoidance of patient travel costs, and more productive dermatologist time (C. Snoswell, Finnane, Janda, Soyer, & Whitty, 2016).

Economic analyses of teledermatology in the context of skin cancer consistently demonstrate that teledermatology enabled earlier melanoma detection is associated with favourable incremental cost effectiveness ratios, as earlier stage melanoma treatment is much cheaper than metastatic disease management and is associated with better survival outcomes. These economic arguments are especially compelling in cash-strapped health economies, where the opportunity to reallocate specialist time away from unnecessary low priority consultations in favour of higher risk patients creates a virtuous circle of efficiency gains (Nikolakis et al., 2024).

Table 3: Barriers and Facilitators to Teledermatology Integration: Global and Pakistan-Specific Perspectives

Domain	Facilitating Factor	Barrier	Pakistan-Specific Context
Infrastructure	Mobile phone penetration (~84%)	Unreliable broadband; rural connectivity gaps	3G/4G expansion underway; PTCL fibre limited to urban zones
Workforce	National Telehealth Authority (NTA) framework	Only ~500 dermatologists nationally	Severe urban-rural maldistribution; majority in Lahore, Karachi, Islamabad
Regulation	PMDC guidance evolving; telemedicine encouraged post-2020	No formal teledermatology licensing framework yet	Legal ambiguity around cross-province prescribing via teleconsult
Literacy & Culture	Young population familiar with apps (WhatsApp widely used)	Low health literacy; privacy concerns; gender barriers in rural women	Culturally sensitive platforms essential; female clinician availability
Disease Burden	High prevalence of treatable skin NTDs (leishmaniasis, leprosy, tinea)	Late presentations; stigma; traditional healers preferred initially	Teledermatology can bridge gap between traditional healer referrals and formal care

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Table 4: Summary of Key Patient Outcomes Metrics: Teledermatology Versus Conventional In

Outcome Measure	Teledermatology Finding	Comparator (In-person)	Quality of Evidence
Diagnostic concordance (overall)	70–91% (SAF); ~80% (video)	Reference standard (in-person)	Moderate–High (multiple RCTs and systematic reviews)
Time to specialist assessment	3–7 days (SAF triage)	42–84 days (conventional referral)	Moderate (observational cohort studies)
Patient satisfaction	82–94%satisfied	87–95% (face-to-face clinic)	Moderate (mixed-methods studies)
Unnecessary referral reduction	40–55% avoidance of in-person visit	N/A (all referred)	Moderate–High (prospective triage trials)
Cost per consultation	20–40% lower person	Higher (travel clinic overhead)	Moderate (health economic analyses)
Melanoma detection sensitivity	80-96%(teledermatoscopy)	84–97% (inperson dermoscopy)	Moderate (prospective diagnostic accuracy studies)

7. CRITICAL COMPARISON OF STUDIES AND METHODOLOGICAL ASSESSMENT

Critical reading of the teledermatology evidence reveals a growing and increasingly rigorous field of research that nonetheless remains limited by several key methodological flaws that limit the certainty with which we can interpret the evidence. We must be aware of these limitations not as an intellectual exercise in pedantry but to ensure that the right level of confidence is taken when clinicians and policymakers apply the evidence (Bourkas et al., 2023).

First, diagnostic concordance studies the mainstay of teledermatology research is constrained by the reference standard. If the reference standard is an in person assessment by a second dermatologist, concordance rates reflect not only the performance of teledermatology but the inherent inter rater variability that exists between any two clinicians regardless of the teledermatology context and that is often in the range of 70-85% even for in person assessments. This limitation suggests that reported teledermatology concordance may represent a theoretical upper bound for any comparative analysis (Whited, 2006).

Second, variability in image quality is a systematic confounding. As such, studies conducted under controlled conditions with standardised image capture procedures using dedicated equipment achieve higher concordance than pragmatic studies reflecting the image quality achieved by minimally trained referring dermatologists or patients who use their smartphones. This quality gradient has practical implications: teledermatology implementation without commitment to image quality and education will likely perform worse than study-reported concordance (Truong, Luu, & Fernandez-Penas, 2025).

Third, the literature is heavily weighted with cross-sectional concordance studies and observational cohorts and includes relatively fewer randomised controlled trials (RCTs). The lack of RCTs reflects the practical and ethical barriers to randomising patients to what may not be as convenient or accessible a pathway of care (raising equipoise concerns) but leaves the field with evidence of moderate quality for its most important outcome claims. The few that have occurred by researchers are well designed, but poorly powered for sub group analyses and have short follow up periods (Chow et al., 2024).

Fourth, this body of literature is subject to publication bias. It is more likely that studies reporting high concordance and good patient

outcomes are published than those showing limited performance, and there is no routine adverse event reporting system in place (e.g. as with pharmaceutical clinical trials). Registry of teledermatology implementation outcomes, including those where the remote examination resulted in a missed or delayed diagnosis would greatly enhance the evidence base (Martyin et al., 2026).

Fifth, and most relevant to this review, the vast majority of published teledermatology evidence is derived from high-income countries mainly the United States, the United Kingdom, Australia and Northern Europe. Applicability of the evidence to LMIC healthcare systems with distinct patterns of disease, standards of image quality, compositions of clinical skill sets and technological capacity is often taken for granted. The limited evidence of teledermatology from South Asia, sub-Saharan Africa and Latin America consistently points to context specific factors playing a significant role in determining the impact of implementation, but the evidence is weak and piecemeal (Bashshur, Shannon, Tejasvi, Kvedar, & Gates, 2015).

8. GAPS IN THE LITERATURE

The above analysis reveals a pattern of strong evidence in limited areas and a lack of evidence in important areas. We list six gaps, which we believe are the highest priorities for research in teledermatology.

Gap 1: Prospective RCT Data on Long-term Clinical Outcomes

The lack of large, well-powered and long term follow up (12 months or more) RCTs is the single most important gap in the teledermatology evidence base. Current RCTs are small, short term, and mostly conducted in high income counties. In the absence of prospective data, the "equivalent" claim for teledermatology compared to face to face care is based on moderate quality evidence, which may not be sufficient for regulatory and reimbursement purposes in conservative health systems (Whited et al., 2013).

Gap 2: Equity and Digital Disparity Analyses

The use and outcomes of teledermatology across socioeconomic, ethnic, age and disability categories is virtually uncharted territory in the literature. Research that has reported global patient satisfaction or outcome measures masks potentially relevant subgroup differences. Lacking evidence, whether teledermatology is mitigating or exacerbating health inequities in dermatology, a question of considerable policy importance, remains unknown (Miller, Ioffreda, Nugent, & Jones, 2023).

Gap 3: LMIC Implementation Evidence

There is a paucity of context-specific implementation evidence from South Asia, sub Saharan Africa and other LMIC's, and what there is is limited and low quality compared with that from high income settings. Teledermatology studies on neglected tropical skin diseases, HIV related skin diseases and tropical skin diseases are especially required (Dovigi, Kwok, & English III, 2020).

Gap 4: AI Performance Across Skin Phototypes

As outlined in section 5, diagnostic performance of AI algorithms across a range of skin phototypes, especially Fitzpatrick IV VI has yet to be well characterised, with most training sets heavily weighted towards lighter skin tones. This is a major scientific and health equity concern. (Vodrahalli et al., 2023).

Gap 5: Adverse Event Reporting and Safety Infrastructure

Structured processes for the identification, reporting and learning from adverse events in teledermatology (missed diagnosis, delays in treatment, communication breakdown) are largely missing from current implementation strategies. Adverse event reporting infrastructure for teledermatology is a critical element of safe scaling (Giansanti, 2023).

Gap 6: Pakistan and South Asian-Specific Evidence

Despite the strong rationale for teledermatology implementation in Pakistan high disease burden, severe dermatologist shortage, high mobile phone penetration, and young, tech-savvy population, as of 2024, there is no existing published evidence on the use of teledermatology in Pakistan's clinical context. This is not simply a theoretical gap; without evidence from the country, the policymakers and health system managers do not have the necessary information to plan and resource programs (Tian, 2017).

9. FUTURE DIRECTIONS

9.1 Technological Innovation

The evolution of the technology of teledermatology is one of increasing functionality at decreasing cost, with some new developments deserving particular mention. Digital dermatoscopes that are sufficiently small to be used with a smartphone and cost less than USD 80 to purchase are now available to allow dermoscopy-quality images to be captured in primary care and other community settings that previously lacked this capability (Lallas et al., 2014) The broad adoption of these devices would significantly elevate the clinical performance ceiling of teledermatology for pigmented lesion assessment (Tommasino et al., 2024).

The ability to visualise in vivo skin microarchitecture at almost histological resolution using confocal reflectance microscopy and optical coherence tomography systems is being successively miniaturised and tested in teledermatology. Although currently costly and needing specially trained operatives, the mid-term capacity to facilitate non-invasive remote evaluation of skin lesion features that currently require biopsy is important.

Wearable sensor technologies for biometric monitoring of transepidermal water loss, pH, erythema index, skin temperature are being trialled for teledermatology monitoring of inflammatory skin disease, especially atopic dermatitis. The combination of objective biometric data with clinical and photographic assessment in teledermatology systems could add significant clinical information to inform remote decision making (Gniadecki, 2025).

9.2 AI Development Priorities

The research needed to advance the use of AI in teledermatology is clear: large and diverse training datasets; prospective validation in real world clinical settings rather than carefully selected experimental data; reporting of performance measures for different skin phototypes; and federated learning approaches that would allow training of AI models across multiple institutions without centralising sensitive patient image data. International standards for validation of AI in teledermatology tools similar to the STARD reporting standards for diagnostic accuracy studies are urgently needed (Xiong, Pfau, Young, & Wei, 2019).

9.3 Policy and Regulatory Development

In most jurisdictions, teledermatology regulations need significant updating to reflect technological and clinical advances. The regulatory challenges include: clarifying licensing and prescribing across jurisdictions for teleconsulting clinicians; minimum standards for image quality and consent for SAF platform operators; and a proportionate risk based approach to AI diagnostic technologies that supports innovation while safeguarding patient safety (Lin et al., 2023).

For Pakistan and other LMICs the regulatory priority is less about fine tuning existing complex regulatory frameworks (which do not yet exist) and more about laying down basic standards that allow safe scaling of teledermatology while preventing regulatory gaps which may lead to patient harm or discourage legitimate use (Sud, 2022).

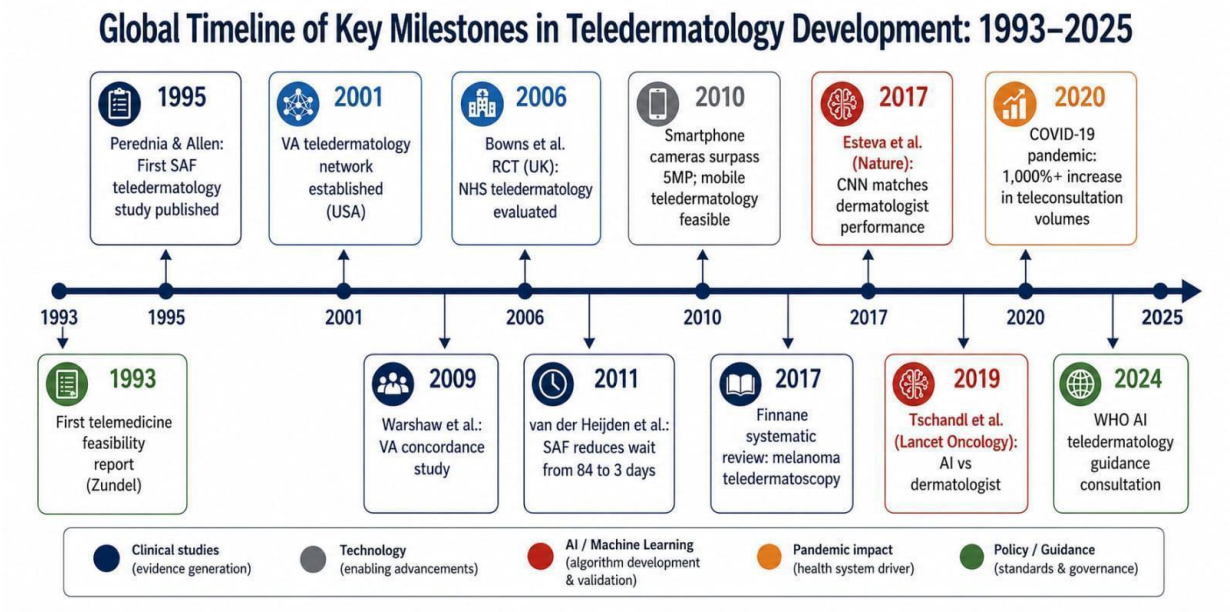

Figure 4: Global Timeline of Key Milestones in Teledermatology Development: 1993–2025

10. PRACTICAL IMPLICATIONS FOR PAKISTAN AND SOUTH ASIA

10.1 The Case for Teledermatology in Pakistan

Teledermatology is an appealing concept in Pakistan for a number of reasons. The epidemiology is clear: with a dermatologist to population ratio of 1:400,000 in a population of more than 230 million, the infrastructure for traditional dermatology care delivery is simply not sufficient to address the problem. The burden of disease includes high prevalence of common inflammatory dermatoses, a substantial and under recognised burden of NMSC in outdoor farm worker populations, endemic cutaneous leishmaniasis in wide geographical areas, and HIV associated dermatoses in high risk groups a spectrum for which teledermatology has been shown to be effective in other LMICs. (Mehmood, 2021)

Meanwhile, Pakistan has digital strengths that are not shared by many LMICs. Smartphone penetration is over 84%, with more than 190 million active SIM subscriptions. WhatsApp and other messaging apps are universally used across socioeconomic classes for personal communication, demonstrating a population level literacy in sharing images via mobile phone that is potentially transferable to SAF teledermatology systems. The young population (median age is less than 23 years) means a high proportion of the population are "digital native" and may overcome the digital literacy challenges that limit teledermatology adoption in older age skewing high income country populations. (Fayez et al., 2024).

Most importantly, Pakistan doesn't have to start from scratch. The National Telehealth Authority (NTA) formed in 2020 is a national telemedicine policy and implementation mechanism. COVID 19 spurred a rapid scale up of telehealth consultations across various specialities, providing operational and institutional expertise to build on for teledermatology. The health insurance scheme of the SEHAT Sahulat Programme Pakistan (SSPP) with more than 40 million beneficiaries from low-income families has the potential to support teledermatology billing if suitable tariffs are developed (Malik, Ong, & Butt, 2025).

10.2 Specific Opportunities and Priority Applications

The highest impact teledermatology use cases in Pakistan can be identified by mapping the burden of disease, current access, and the teledermatology evidence base for the disease. Four stand out. First, triage and management of cutaneous leishmaniasis: significant endemic areas in Balochistan and KPK are distant from dermatological resources, and SAF teledermatology linking peripheral health care facilities to metropolitan dermatology centres could dramatically reduce delays and inappropriate treatments, known to occur with current management (Pathak, Patel, Alani, Belle, & Lipner, 2025).

Second, skin cancer screening in high risk outdoor worker populations: Pakistani farmers, construction workers and long haul truck drivers are exposed to significant UV radiation with no skin cancer screening. A community health worker driven SAF teledermatology service with Lady Health Workers (LHWs) trained in capturing teledermatology images could provide substantial triage and early detection capabilities to these workers at low marginal cost per case. (E. Rashid, Ishtiaq, Gilani, & Zafar, 2003; Gao & Oakley, 2023).

Third, monitoring of chronic inflammatory diseases: teledermatology follow up of stable psoriasis, atopic dermatitis and vitiligo patients that occupy precious face to face dermatologist clinic time would liberate dermatologist capacity for more challenging and urgent cases, enhancing the efficiency and clinical team of the dermatology care system. Fourth, dermatology training: teledermatology systems can be used as a two way clinical education platform, allowing GPs and LHWs in remote areas to receive formal feedback on teledermatology assessments by dermatologists, which may lead to improved dermatology knowledge over time (Finch, 2008).

10.3 Addressing the Barriers

To scale teledermatology in Pakistan, it is important to methodically address the barriers outlined in Table 3. Network issues in rural Balochistan, Sindh and tribal KPK can be somewhat overcome through asynchronous SAF approaches that work on 2G/3G and through offline first apps that save patient data for upload when network connections are established. Teledermatology workflows using USSD, which do not require a smartphone or data plan have been successfully implemented in sub Saharan Africa and should be trialled in the poorest settings in Pakistan (Kazi et al., 2020).

A specific consideration in Pakistani health care is gender. Female patients who encompass a significant proportion of the burden of disease for inflammatory dermatoses in particular may not be willing to share skin images with male clinicians whom they have not met prior to the consultation, or may encounter family or cultural barriers to video consultation. Design considerations of the teledermatology platform that support choice of female consulting clinicians, that support the role of mahram (close relative) compatible family members in video consultations and the provision of culturally sensitive information and communication resources are critical to equitable access (Kanwal, Tabassum, & Qadri, 2022).

Paucity of regulatory and medicolegal guidance is perhaps the greatest impediment to scaling teledermatology services. Guidance from the Pakistan Medical and Dental Council (PMDC) regarding clinical obligations in teledermatology, prescription authority across provinces, documentation and liability is needed to enable institutional health care providers and academic dermatology departments to confidently scale teledermatology services. Lobbying by dermatology professional societies, especially the Pakistan Association of Dermatologists (PAD) will be crucial in moving this process along (Hussain, 2004).

Table 5: Recommended Actions for Teledermatology Integration in Pakistan: A Prioritised Implementation Framework

Priority Area	Recommended Action	Responsible Entity
National Policy Framework	Develop binding teledermatology guidelines under NTA umbrella; define standards for image quality, consent, and data retention	Ministry of National Health Services (NHS), NTA, PMDC
Workforce Training	Integrate teledermatology modules into MBBS and postgraduate dermatology curricula; train LHWs in clinical photography	CPSP, Medical Colleges, Provincial Health Depts
Technology Infrastructure	Subsidise smartphones and portable dermatoscopes for Basic Health Units; leverage USSD-based SAF for low-bandwidth areas	IT Ministry, BISP digital health wing, NGO partnerships

Priority Area	Recommended Action	Responsible Entity
Reimbursement Model	Pilot teledermatology-specific CPT equivalent billing codes under SEHAT Sahulat Programme; evaluate and scale	Provincial Health Departments, Insurance bodies
Research & Evaluation	Fund prospective teledermatology RCTs and cost-effectiveness studies in Pakistani settings; establish national skin disease registry	HEC, PMRC, Academic Dermatology Centres

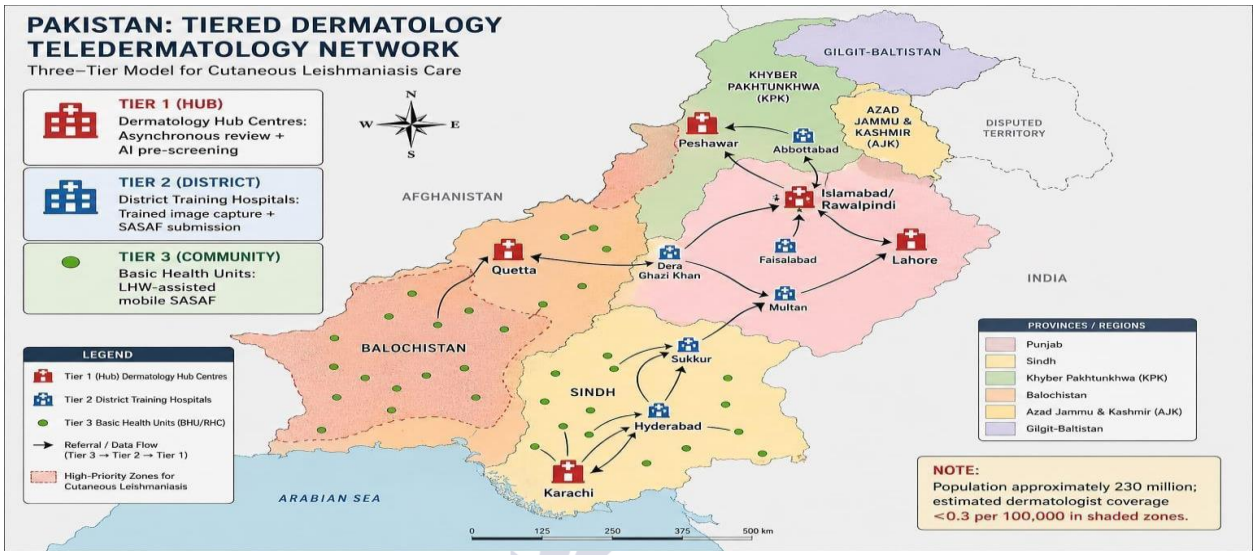

Figure 5: Proposed Teledermatology Hub and Spoke Network for Pakistan: Geographic Coverage and Implementation Priority

11. CONCLUSION

Teledermatology has passed the point of being an innovative curiosity to being an evidence based practice. The available evidence is reasonably confident that store and forward and synchronous video teledermatology achieve diagnostically significant concordance with face-to-face dermatological examination for a wide range of conditions; that they reduce the wait time to a dermatologist by weeks to months; that they enhance patient satisfaction and don't adversely impact clinical outcomes in carefully selected patients; and that they save money for health systems and patients when deployed with appropriate governance and quality assurance measures.

The evidence is not without its limitations. It is heavily weighted by studies from high-income settings, disproportionately centred on cross-sectional concordance rather than longitudinal clinical outcomes designs, and absent in its consideration of the equity issues associated with digital health technologies in different subgroups of the population. The AI component is promising, but not fully validated, and confounded by demographic skewing of training data makes the need for better, more representative, and transparent research all the more pressing.

In the specific context of Pakistan and similar regions in South Asia, this review finds that the teledermatology opportunity is strong and the challenges, though formidable, not impossible. The combination of severe specialist deficit, a high and geographically dispersed burden of disease, considerable mobile infrastructure, a young, tech-savvy population, and emerging but real institutional support for telemedicine is a real opportunity. Achieving this will require concerted efforts in the domains of regulation, education, technology and research and will require the dermatological professional community in Pakistan to step up and take a leading role in the teledermatology debate.

The common skin diseases of low-income communities in the most remote valleys of Balochistan and the most densely populated squatter settlements of Karachi are worthy of the

same specialist diagnostic care as those referred to tertiary centres in Lahore. Well-conceived and well-evaluated teledermatology is one of the most accessible and powerful methods of achieving this.

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