Digital future of dermatology

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Abstract

Evolution of technology in the past several decades has undeniably transformed the practice of medicine. Dermatology, a field relying on visual cues, has been particularly impacted by advancement in imaging technologies. The purpose of this study was to review the current status as well as digital future of dermatology. The PubMed database was searched for articles pertaining to digital dermatology using search terms digital dermatology, teledermatology, and dermatopathology education. Digital dermatology has found a role in almost every aspect of dermatology: research, dermatology education and training, and clinical practice including disease prevention, diagnosis, treatment, and patient follow-up. Smartphone applications such *VisualDx, MyDermPath, YouDermoscopy* serve as diagnostic aid tools and can also help increase the user's knowledge of dermatology. Tools such as multispectral digital skin lesion analysis (MSDSLA) improve diagnostic accuracy and lead to fewer unnecessary biopsies. Teledermatology increases patient satisfaction, as they are able to experience shorter waits times and decreased costs. Underserved communities and those in rural settings are more likely to have a dermatologic evaluation by a specialist via teledermatology. Addressing important topics such as legal framework and updating reimbursement policies will allow for a smoother incorporation of digital dermatology into clinical practice and likely benefit patient care.

Keywords: teledermatology, digital dermatology, dermatopathology education, diagnosis, treatment, adherence, reimbursement, patient privacy

Introduction

Medical care has rapidly transformed over the past several decades owing to advances in technology and continues to do so at an accelerated pace. Computers, smartphones and mobile applications, electronic health records, and electronic prescribing are just some of the examples of how technology has become integral to health care delivery. Dermatology, a field relying on visual cues that can be easily captured by imaging technologies, has particularly experienced the advancements in technology. Delivery of high-quality dermatologic service has become possible even when the patient and the provider are separated by both time and space thanks to the advancements in telecommunications technology [1]. Recently, a computer algorithm was able to distinguish between biopsy-proven benign and malignant skin lesions on par with board-certified dermatologists [2]. Emerging technologies have been vastly implemented into dermatology education and day-to-day clinical practice. Evolution of digital and smartphone technology has turned clinical photography into an important aspect of training next generation of dermatologists as well as managing dermatological pathology [3]. Dermatologists may continue to use new tools in their practice to improve patient outcomes and increase efficiency [2]. The purpose of this study was to review the current status as well as digital future of dermatology.

Methods

The PubMed database was searched for articles pertaining to digital dermatology. Search terms included digital dermatology, teledermatology, and dermatopathology education. The search was limited to English articles published in the past 10 years.

Results

1.1 Training

1.1.1 Current

Technological advances and virtual resources are transforming dermatology education (Table 1). Dermatology is a highly visual field and clinical images are of vital importance in the training process. Most attending and resident physicians own smart phones, making smartphone applications (apps) a practical, portable, and accessible educational tool [4].

Multiple apps are available to facilitate study. *VisualDx* allows users to quickly search and view a summary of a disease. Alternatively, the user may enter components of the physical examination and receive a list of probable diagnoses [5]. Other apps are available to test the user's knowledge of dermatology. For example, *YouDermoscopy* allows users to practice their diagnostic skills by viewing and identifying dermoscopy images of varying difficulty [5]. *MyDermPath* includes over 2,000 images and 1,100 diagnoses allowing users to take notes, access quizzes, upload images, and review key clinical information [4].

Technology allows dermatopathology images to be scanned, saved, and widely distributed. Hundreds of trainees can view the same slide from various locations [6]. Rather than rely on grey-scale images in textbooks, residents are now able to study full-color images [7]. Virtual microscopy is frequently used in dermatopathology education. One study aimed to evaluate the diagnostic accuracy between traditional glass slide microscopy and virtual microscopy. A 48-question examination was given to 35 dermatology residents from three different programs. Half the questions utilized glass slide microscopy and half used virtual slides. Diagnostic accuracy was better with glass slides than virtual slides overall (P=0.01). Second- and third-year residents scored higher with glass slides. However, there was no statistically significant difference in accuracy between the two methods for first-year residents (P>0.99), [8].

An additional randomized study of 8 dermatology residents and 13 pathology residents and fellows compared the diagnostic accuracy of both virtual and glass slide microscopy. Participants were randomized to view 12 questions using one of the modalities. No significant difference existed between the two groups (P=0.0008). Through follow-up questionnaire, trainees reported glass slides were easier to use than virtual slides (P=0.012). Minor issues in viewing the virtual slides were reported by 65% of participants and these included delayed loading time and insufficient magnification. A preference for glass slide microscopy was expressed by 75% [9].

Teledermatology (TD) has the ability to improve access to dermatologic education for both dermatology trainees as well as those entering other specialties [10,11]. A 2014 study aimed to evaluate residents' and students' perception of TD as a teaching method. This study surveyed trainees involved in the TD program at the Denver Department of Veterans Affairs Medical Center. Residents evaluated TD cases prior to confirming the diagnosis with an attending physician. Medical students observed. A survey assessed the usefulness of TD in teaching patient care, medical knowledge, practice-based learning and improvement, interpersonal and communication skills, professionalism, and systems-based practice and 14 residents and 16 students completed the survey. Teledermatology was reported to be a valuable educational tool by 88% of the residents and 79% of the students. The categories of practice-based learning and medical knowledge had the highest satisfaction ratings. Lowest satisfaction was reported for the areas of professionalism, interpersonal skills, and communication skills [10].

Teledermatology provides the opportunity for resident physicians to address a large volume of dermatology consults under supervision. A

prospective study evaluated concordance in diagnosis and management between resident and attending physicians. Nine attendings and nine residents received 84 consults and diagnosed 90 conditions. Complete concordance was found in 53% of diagnoses and 65% of management plans. Partial concordance for diagnosis and management was reported in 39% and 24% of cases, respectively. The results of this study suggest that TD is a promising method of learning for residents [12].

1.1.2 Future

Education and examination of dermatology trainees is evolving to a more virtual approach [8,9]. The increased availability of educational resources is a wider-reaching and more cost-effective means of meeting the increased demand for dermatology education [6]. Additional advantages to digital education include flexibility and portability [13].

Advances in technology allow for an interactive web-based learning experience. Competency examinations based on virtual microscopy allows training programs to evaluate the performance of their residents against other residents in the nation [6]. Additionally, TD helps programs assess residents' knowledge, communication skills, and ability to adapt to different healthcare delivery systems and coordinate care [11].

Trainees and attendings are more frequently turning to digitally formatted journals rather than traditional print copies [14]. A similar trend is reported for textbooks, with more readers downloading digital versions of the text. This shift allows educational materials to become more interactive through incorporation of tables, videos, charts, quizzes, images, and links to similar peer-reviewed articles [14].

A systematic review of 12 studies evaluated the effects of digital dermatology education on knowledge, skills, and satisfaction. Of the trials evaluating knowledge, two of 9 reported an improvement compared to traditional education. Enhancement with digital education was reported in three of 5 studies evaluating skills. Of the studies measuring participant satisfaction with digital dermatology education, three of 5 stated high satisfaction. Although supporting the potential benefits to digital dermatology learning, results of this systematic review are mixed and inconclusive overall. Additional research is needed to determine the efficacy and most appropriate role of digital education in dermatology [13].

The role of TD in education is increasing. A 2014 survey of 56 dermatology programs reported that 47% were already using telemedicine as part of their curriculum. Live interaction was used 35% of the time whereas store-and-forward was used 85% of the time. Teledermatology education for students was offered in 21% of the programs associated with a medical school. The majority of programs (68%) reported interest in incorporating telemedicine into their training process. This study supports the development of a TD curriculum for future dermatology training [15].

The use of TD in education decreases the amount of face-to-face time trainees have with patients and supervising attendings. This allows professors to reach a larger audience with each lecture. As TD becomes increasingly available, the need for teaching professors may decrease. Additionally, the use of TD may eventually decrease the number of practicing specialists to train future dermatologists. Decreased availability of in-person clinical education would increase the need and demand for digitally based education [16].

The easy shareability of digital images and patient cases through TD allows trainees to study rare cases in addition to common dermatologic complaints [16]. The abundant access to clinical images will likely continue to improve trainee's diagnostic skills [10]. Since TD allows the study of more cases in a shorter period of time, it will potentially decrease the in-person time trainees spend with their patients. In this situation, decreased face-to-face time, inability to palpate lesions, and lack of opportunity to ask follow-up questions may negatively affect the trainee's ability to conduct a physical examination and build a relationship with the patient [10,16].

An estimated 90% of medical students use at least one social media platform [17]. Social networking sites function as a means of sharing images and

information with an audience spanning the nation and the globe [18]. Social media is a free method of distributing information, collaborating with peers, and facilitating discussion, making it appealing as an engaging educational tool [19].

In a meta-analysis of 14 studies concerning social media and medical education, learner engagement was the most commonly reported advantage [20]. Creation of interest groups, polls, videos, and quizzes via Twitter and/or Facebook can boost trainee engagement and participation [19]. One study of 80 students at Northeast Ohio Medical University evaluated the effects of once-weekly online quizzes on second year medical student motivation. Each week, a 10-question quiz was announced via Twitter and Email: Small prizes were awarded to the first participant to correctly complete each quiz. Online quizzes, with incentives, can promote motivation through competition and improve online student-faculty communication [21].

Educational collaboration is a potential benefit of social media among residents and attendings. To assess the current and potential use of social networking in dermatology, surveys were distributed through the American Society for Dermatologic Surgery and Association of Professors of Dermatology. Respondents included 52 faculty members and 85 dermatology residents. Current use of online educational materials was reported by 86% of residents and 81% of faculty and 39% of residents stated online materials are essential to their education, compared to 21% of faculty. When asked if they were interested in greater collaboration with peers across the nation, 80% of residents and 88% of faculty responded affirmatively. The belief that a social networking site could improve educational collaboration in the field of dermatology was reported by 94% of residents and 87% of faculty [22].

Social media's role in education will likely continue to expand [23]. Owing to busy schedules, residents may be limited in the number of trainings and conferences they are able to attend. Social media overcomes this obstacle to education by providing access to material when convenient for the user [19,23]. Although not recommended as a replacement for traditional didactics, social media may be an effective learning tool and warrants further research [19].

1.2 Prevention

Education, diagnosis, and treatment are the most recognized components of digital dermatology. In addition, the digital approach to dermatology may also be beneficial in the prevention of disease. The age of smartphones, apps, and advanced technology presents an opportunity to increase patient risk awareness and avoidance [24].

1.2.1 Measuring exposures and behaviors

Monitoring of personal ultraviolet (UV) radiation exposure is helpful for skin cancer prevention [25]. Original UV-sensing wearable devices were bulky and didn't allow for convenient concurrent sunscreen use [24]. The recent advances in technology have produced thin, comfortable, breathable, wearable UV sensors [26].

The application of a UV-sensing patch was evaluated both with and without sunscreen use. Subjects wore a UV patch with sunscreen, a UV patch without sunscreen, and a Scienterra dosimeter. The readings were in agreement between the dosimeter and the patch without sunscreen; the patch with sunscreen showed a significant reduction in UV exposure ($P<0.0001$). The thin, flexible patch is attached to the skin and changes color with UV exposure. A smartphone app is then used to quantify the change in color with the level of exposure. The app then calculates the user's level of risk based on skin type and gives a recommendation on the most appropriate sunscreen [24].

The development of smartphone and smartwatch UV-sensing capabilities has been proposed as a means of improving exposure awareness. Smartphones and smartwatch sensors would eliminate the need for a separate wearable device. Improved convenience and access would potentially increase the use of UV sensors [27]. Paired with interactive apps, these UV sensors would likely promote a healthier lifestyle. Monitoring capability of apps would give users the ability to set and track goals [28].

Several conditions in dermatology practice require frequent monitoring. In addition to monitoring

exposures, TD is useful in treatment and behavior monitoring. A retrospective study used a web-based survey to evaluate smartphone monitoring in 123 patients who received laser resurfacing. Participants sent daily photographs of their skin. Providers were able to educate and reassure patients on expected side effects during the healing process. Smartphone monitoring participants required fewer face-to-face follow-up appointments. Experts postulate that as digital monitoring becomes available more patients will request this method of follow-up [29]. An additional randomized controlled study in acne patients on isotretinoin treatment found those in the telemonitoring group experienced less side effects than those in the control group [30].

Teledermatology was used to monitor 19 psoriasis patients on biologic therapy. Patients were given smartphones to be used for weekly digital follow-up for 6 months. Face-to-face visits were conducted every four weeks. Psoriasis Area and Severity Index (PASI), image quality, patient questionnaires, and the handling of adverse events were evaluated. Over the course of the study, 338 mobile visits were carried out and 1,112 images were transmitted and 95% of the digital images were sufficient to assess PASI. The TD system was able to address all 155 adverse events. Willingness to use personal mobile phones for service in the future was expressed by 70.6% of patients who completed the questionnaire. In addition, 88.2% thought the TD system was a "very good idea" and 94.1% would recommend it to other psoriasis patients. Teledermatology is a reliable method of monitoring for psoriasis patients on systemic therapy. It empowers patients, reduces the number of unnecessary face-to-face visits, and holds a promising role in the future of dermatology [31].

1.2.2 Monitoring lesions

Since early diagnosis of skin cancer improves treatment outcome, suspicious lesions should be monitored closely [32]. Teledermatology combined with digital follow-up may be a cost- and time-effective method of monitoring suspicious lesions, especially in patients for whom a dermatology clinic is not readily available [33]. Digital follow-up involves total body photography and digital dermoscopy. This method improves diagnostic accuracy and earlier detection of melanoma [33].

The convenience and feasibility of TD make it an asset in short-term lesion monitoring. Patients are able to obtain images for follow-up themselves using their smartphones. This decreases the need for face-to-face visits [34]. A prospective cohort study of 29 patients with atypical nevi compared dermoscopic images obtained in the office with iPhone images obtained by the patient. Lesions were followed for 3-4 months. Images satisfactory for evaluation by a teledermatologist were obtained by 97% of the patients. Management decisions made by the teledermatologist and in-office dermatologist were then compared. Concordance between the two groups was calculated at 97%. Although additional research is needed, TD is a convenient, efficient method of atypical nevus monitoring [35].

1.2.3 Intervening in exposures and behaviors

Daily health monitoring is a potential benefit of apps with their ability to store, track, and transfer information [4]. Use of this technology is commonly utilized to assist in weight loss. Self-awareness and accountability may increase as patients record their health-related behaviors [36]. A similar concept could be used in the field of dermatology to help patients recognize personal risks, habits, and the need for behavior modification [24,37].

1.3 Diagnosis

1.3.1 Smartphone apps

Studies are emerging concerning the role of smartphones in diagnosis of skin cancer and lesion monitoring. Self-diagnostic applications on smartphones, although not approved by the Food and Drug Administration (FDA), are emerging as a means whereby patients assess the likelihood of a malignant lesion. However, these apps are in need of improvement [38,39]. A 2013 study of the leading self-diagnosing melanoma apps found that three of the four apps incorrectly diagnosed 30% or more lesions as benign [40]. A later study of 195 lesions found a sensitivity of 73% and specificity of 83% for smartphone application diagnosis compared to 88% sensitivity and 97% specificity for clinical diagnosis by a dermatologist [41].

Advances in technology may increase the accuracy of self-diagnostic apps. These improvements may result in earlier diagnosis and treatment to provide a better outcome. However, the current lack of FDA regulation is a reason for concern and no physician is consulted during use of a self-diagnosing app. To avoid late detection of melanoma, patients should not rely on a negative diagnosis from a self-diagnosing app. If concerned about a lesion, a face-to-face examination from a dermatologist is still the gold standard and should be used to confirm smartphone results [39].

1.3.2 Teledermatology

Teledermatology consultations can be live and interactive using videoconferencing or they can be 'store and forward' with electronic digital images of a lesion sent to a dermatologist for review at a later time (**Figure 1**). Teledermatology provides primary care physicians a means to access the opinion of a specialist dermatologist if concerned for a suspicious lesion without referring patients through the traditional pathway [42]. In a retrospective chart review of 7,960 veterans seen by store-and-forward teledermatology (SFT), of the 61 veterans that met inclusion and exclusion criteria, 45 (74%) melanomas were diagnosed correctly and 57 (93%) were correctly managed. In some settings, diagnostic and management accuracy of melanoma in SFT is comparable to face-to-face dermatology [43]. Incidence of detected melanoma, keratinocytic carcinomas, and any skin cancer was similar in patients evaluated by SFT (N=434) and face-to-face consultation (N=587) when adjusted for age, immunosuppression, and personal and family history of skin cancer in another retrospective cohort study. The two cohorts also had similar pre-post biopsy diagnostic concordance, time from initial consult request to biopsy (45.5 days versus 47.3 days, P=0.8) and time from biopsy to definitive treatment (67.5 days versus 65.4 days, P=0.8), [44].

1.3.3 Multispectral digital skin lesion analysis

Multispectral digital skin lesion analysis (MSDSLA) is a tool that uses bands of visible and infrared light to image and analyze pigmented skin lesions (PSLs) and determines the degree of morphologic disorder using measuring the distribution of melanin using algorithms. In a study evaluating how MSDSLA impacts the biopsy decisions of dermatologists and nondermatologists following clinical and dermoscopic evaluation of PSLs, sensitivity for the detection of melanoma or other high-grade PSL on clinical and dermoscopic increased from 70 to 88% after using information provided by MSDSLA (P<0.0001) whereas specificity increased from 52% to 58% (P<0.001). Review of MSDSLA findings also improved diagnostic accuracy from 59% to 69%

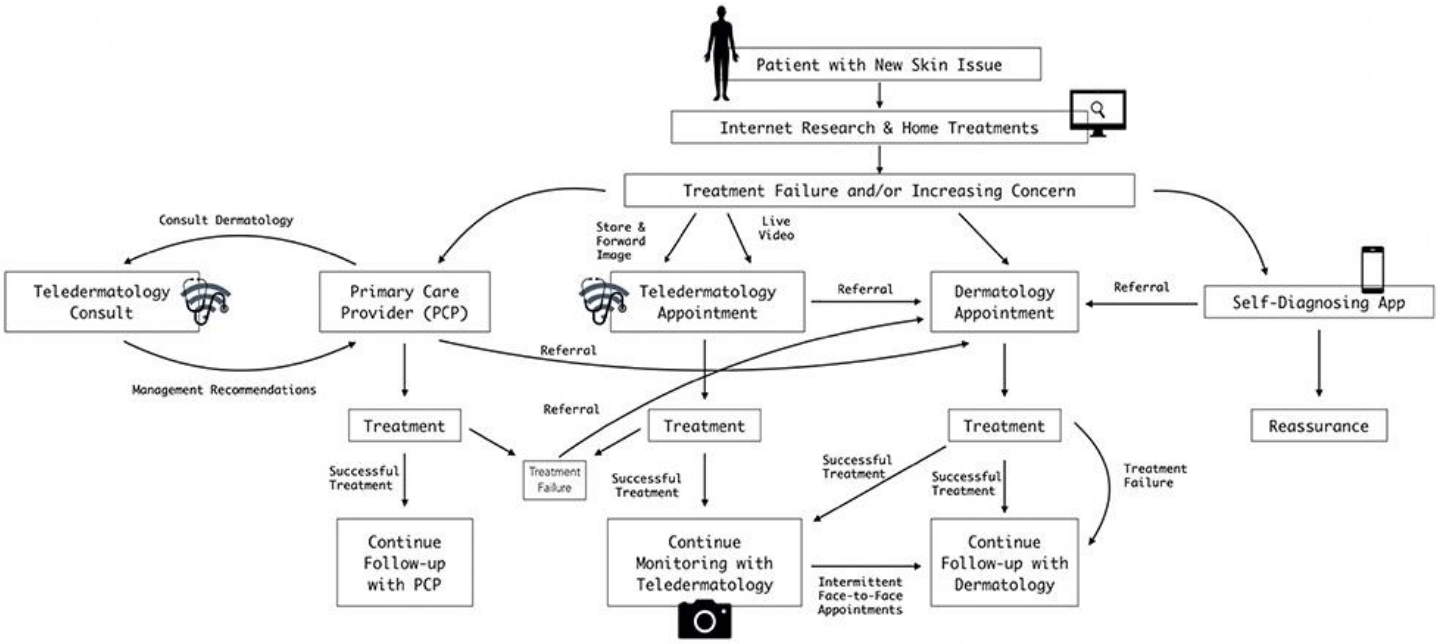

Figure 1. *Digital future of dermatology.*

(P<0.0001) and led to fewer unnecessary biopsies and an improved biopsy ratio (ratio of melanomas biopsied to total biopsies), [45].

1.4 Treatment and adherence

1.4.1 Initial treatment and follow-up

The convenience and feasibility of TD may provide earlier initial evaluation and treatment [46]. A pilot study of 79 TD consults from an outpatient primary care clinic found that TD reduced the median time to evaluation from 70 days to 0.5 days when compared to an in-person dermatology clinic visit. The median time to treatment was decreased from 73.5 to 3.0 days [47]. Digital dermatology allows patients to complete health information forms, send photographs to their physicians, make appointments, and participate in consultations online [48]. In areas without access to a dermatologist, TD is beneficial for providing earlier and wider-reaching access to care. An estimated 75% of TD patients live in remote locations. Teledermatology is being used to help patients in rural settings requiring dermatologic care [49]. Additionally, the time- and cost-effectiveness of TD makes it possible to evaluate and treat more patients in less time than traditional office visits [46].

A review found high treatment concordance between TD and in-office management [32]. One observational study of skin cancer screening found an 81% concordance rate between TD and face-to-face examinations [50]. An additional evaluation comparing diagnosis and management from a teledermatologist and in-person dermatologist found 89.7% of cases were either completely or partially concordant [47].

Teledermatology can be a more efficient method of follow-up. Patients with no complaints or concerns can be evaluated without the need for a face-to-face visit [29]. For example, patients can send photographs or participate in TD video calls to assess treatment progress, monitor concerning lesions, or follow-up after procedures [29,30]. Some experts recommend initial consult should be in-office if possible. This gives providers the opportunity to initially examine the patient face-to-face, build a rapport, and educate them on the most appropriate use of TD and apps for monitoring and follow-up visits [51].

1.4.2 Registry of diseases and medications

A patient registry collects data through observational study methods to evaluate outcomes in a target population [52]. Patient registries serve as valuable resources to increase knowledge of dermatologic diseases [53,54]. Numerous registries exist in dermatology. A 2016 review identified 48 dermatology patient registries representing 23 diseases [54]. These registries are used for long-term evaluation on course of the disease, effectiveness of treatment, and quality of life. The need for patient registries is increasing [55]. Findings from the observational studies used in registries can be used to design and recruit participants for prospective trials. Improving data collection, documentation, and sample collection paves the way for increased understanding of disease pathogenesis, diagnosis, and treatment in the future [53].

1.4.3 Adherence to treatment (monitoring and accountability)

Barriers to adherence and treatment success in TD include inadequate communication among providers and care fragmentation [47]. Initial TD consults often come from a primary care provider (PCP), making the PCP responsible for follow-up. The availability of electronic prescriptions increases the concordance rate between the teledermatologist and the PCP. A study of 79 TD consults from a PCP office found that 93% of the PCPs followed the management recommendations provided during a TD consultation [47].

Frequent follow-up promotes greater adherence. This effect has been referred to as "white coat compliance" [56]. As discussed previously, TD is a cost- and time-efficient method of patient follow-up, especially for patients with limited access to dermatologists [32,46]. The use of technology and TD for patient monitoring is increasing; improving patient adherence is one of the many benefits of TD (**Box 1**). The current digital age provides many tools for increasing patient adherence and accountability including apps, online portals, and reminder systems [47].

Online patient portals are becoming more common in today's healthcare system and offer several benefits. Patients' ability to interact with their healthcare providers online increases satisfaction, promotes adherence, improves treatment results, and decreases costs. Chat or message features offered through portals allow for timely answers to simple questions, thus eliminating some unnecessary face-to-face appointments [57]. Online portals also give physicians the opportunity to provide reliable educational resources to patients [58].

Patient education also increases adherence [59]. Noncompliance and treatment failure is more common with lack of patient knowledge [58]. Education is a target of many existing and developing dermatology apps. The visual nature of dermatology provides the opportunity for incorporation of apps into patient education [60]. Possible benefits of app utilization include increased awareness of concerning lesion changes, expected adverse effects, and use as medication reminders [58]. Although apps are promising as a future tool for increasing adherence, improvements and increased regulation are needed to ensure the distribution of safe, unbiased information to patients [60].

Digital reminders can be utilized to promote adherence in dermatology. Multiple studies have assessed the use of technology on patient adherence. A randomized controlled trial evaluated the use of daily text message reminders on sunscreen application in 70 patients. Adherence was measured for 6 weeks using electronic monitors. Daily mean adherence rate was 56.1% for the text message group versus and 30.0% in the control group ($P<0.001$), [61]. An additional study assessed the effect of text messaging on adherence in 40 plaque psoriasis patients. Adherence increased from 3.86 days per week to 6.46 days per week in the test group ($P<0.001$), [62]. A weekly internet-based survey administered over 12 weeks was found to increase adherence in 20 acne patients from 32% to 74% ($P<0.01$), [63]. Online video-based education was found to be beneficial in increasing topical sunscreen application from 0.2 days per week to 1.9 days per week ($P<0.001$), [49].

1.5 Patient satisfaction

Digital dermatology provides a variety of benefits [46]. In a Dutch survey regarding digital tools in health care, patients reported the possibility of connecting with providers online, requesting prescription refills, sending photos, frequent follow up, and ability to review visit notes as advantages to using TD and an online patient portal. Decreased face-to-face time with the provider and concerns over patient privacy were identified as disadvantages to TD [64]. Lack of follow-up with the same physician has also been listed as a patient concern [65].

Patients have reported satisfaction with the easy use and shorter waiting times associated with TD [66,67]. A prospective study involving 300 patients compared TD with face-to-face visits. Mean waiting times were reduced from 114 days to 39 days in patients in TD versus face-to-face. Those in the TD group also experienced a 14% decrease in cost [66]. From a survey of 123 TD patients, 93% reported satisfaction with their experience and 86% reported that it was more convenient than an in-office visit [65]. In an additional prospective study, 197 parents of children age 6-17 years evaluated their satisfaction concerning a mobile TD app. Satisfaction with the app was reported in 87% and 93% reported they would use it again [68]. In a poll of 35 dermatology patients, the majority reported they were willing to pay for TD services [69].

A 2018 systematic review investigated patient and provider satisfaction in store-and-forward and live-interactive TD; the review included 40 studies. Of those involving store-and-forward TD, 96% of patients and 82% of providers reported satisfaction.

Box 1. *Benefits of teledermatology.*

More frequent follow up
Easier patient monitoring
Increased adherence
Increased awareness of concerning lesion changes
Awareness of expected adverse effects
Use as medication reminders
Improved treatment results
Decreased costs
Timely answers to simple questions (less unnecessary face to face contact needed)
Provide reliable educational resources

Studies involving live-interaction determined satisfaction rates of 89% patient satisfaction and complete provider satisfaction [70]. Although overall satisfaction with TD is high, a controlled study still reported a preference for in-person examinations when 210 dermatology patients were examined in-person, by store-and-forward TD, and by video TD. Patients and dermatologists were asked to rank their preferences. Both patients and dermatologists reported a significantly higher preference for in-person examination (P=0.001), [71].

1.6 Legal framework

Increased use of TD and technology in dermatology raises new ethical and legal considerations [3,72]. When utilizing digital dermatology in practice providers should continue to abide by their state regulations and operate within their scope of practice. Providers should also confirm that TD services are covered under their current malpractice insurance policy [73].

1.6.1 Documentation

The American Telemedicine Association (ATA) issued guidelines for the most appropriate use of TD. Each TD consultation should be fully documented and information should be stored in a form in accordance with the Health Insurance Portability and Accountability Act (HIPAA), [73]. Records should be kept detailing data transmission. Written consent is required for all recorded video consults [73,74].

Clinical photography is important in dermatology for education, diagnosis, and surveillance purposes. Caution should be exercised to maintain patient privacy and high ethical standards when using patient images. Use of smartphone cameras in the clinic has increased in the last few years and will likely continue to do so [3]. A 2013 survey of 20 dermatologists found that all 65% who responded to the survey use their smartphones to photograph patients. Of these, 85% reported having over 100 patient images on their personal phones. In addition, 92% admitted to texting or e-mailing images to peers for a second opinion. Only 15% recorded patient consent for clinical photography in the chart. Verbal consent was obtained in 92% of cases. Although there is a degree of implied consent in clinical photography, it is recommended that providers document consent to protect patient privacy. Failing to obtain and document informed consent for clinical photography leaves the physician legally vulnerable [3].

1.6.2 Patient privacy

The Health Insurance Portability and Accountability Act (HIPAA) protects the privacy of patients. Protected health information (PHI) includes photographs revealing the identity of patients, including full facial images. For identifiable images, written consent must be obtained for transmission of PHI for reasons other than treatment, payment, or healthcare operations. Administrative, physical, and technical safeguards should be installed to protect patient information [75].

The location of TD should provide auditory and visual privacy for both the patient and the provider. All individuals present for the consult should be identified, visible, and able to be heard. Technology must be kept updated with antivirus and security software. Devices should be password protected and timeout with inactivity. All PHI should be encrypted [73].

Smartphone and digital cameras are not secure unless additional security measures are installed. Security codes may be used to protect information stored on smartphones [3]. In the event a smartphone with PHI is stolen, users should have the ability to remotely delete stored information [73]. Digital cameras typically cannot be encrypted or password protected. Cameras containing any identifiable information should be locked in a secure area when not in use [75]. Regularly downloading images to a secure computer and deleting them from the camera is recommended to protect patient privacy [3].

As medical photography becomes more prevalent, policies should evolve to protect both patients and providers [75]. In a survey of 101 dermatologists, only 22% were familiar with policies covering smartphone use in their clinics [76]. A specialty-wide consensus would be beneficial to guide the appropriate use and storage of clinical photography in dermatology [76,77].

With the increasing use of dermatology apps by both providers and patients, regulation concerning patient privacy and physician liability must be

determined. Unique issues of privacy, liability, and security related to apps require an updated legal framework. Although most developers regard the FDA guidelines as law, the FDA regulation of mobile apps is nonbinding. Physician use of apps to communicate with other physicians may raise issues of cross-jurisdictional practice and licensing [72]. Unknown malpractice concerns accompany the relatively new role of apps in healthcare, possibly increasing physicians' legal vulnerability. Moving forward, developers and physicians should remain attentive to the changing standards and guidelines regarding mobile app use in healthcare [72].

1.6.3 Reimbursement

Business models must evolve to accommodate the use of TD in today's healthcare system [78]. For TD to be successful, it must be an efficient and sustainable practice. Adequate training, reliable software, high quality images, and incorporation into existing electronic medical record systems are important to increase efficiency of TD [79].

Reimbursement varies from state-to-state and poses a challenge to the incorporation of TD into practice [80]. In a survey of teledermatologists, 71% reported difficulty obtaining reimbursement for TD services and 94% recommended improving the mechanism and timeliness of reimbursement. In addition, 94% also reported financial compensation as the key to incentivize other dermatologists to participate in TD to improve access to care [79]. The role of TD will likely increase with the implementation of reimbursement policies [80].

Discussion

Over the last 10 years, the use of teledermatology in everyday practice has become more prevalent, especially as various technologies have become more accessible. Digital dermatology has found a role in almost every aspect of a patient's experience. This review article provides an overview of the current uses of teledermatology, its advantages, limitations, and future directions. Multiple studies have shown its widespread use in resident education, especially in dermatopathology. Many physicians wish to see digital dermatology used more in their training programs. Teledermatology also proves multiple purposes in disease prevention, diagnosis, and treatment. Patients themselves are satisfied with TD as they are able to experience shorter wait times and decreased costs. It is important to consider the new ethical and legal limitations of TD, including changes in documentation, patient privacy, and reimbursement models.

Residency programs should consider including more digital dermatology for didactic sessions. Many physicians and trainees do appreciate the benefits of TD for educational purposes. Even 20 years ago, dermatologists recognized the immense benefit that could come from creating a database of clinical images that would be accessible over the internet and provide a remarkable teaching and reference tool [81].

We believe that more formal education is needed in learning how to use TD for patient care. Currently, residency programs such as Emory and Harvard include several months of teledermatology training as a part of the formal curriculum. One-year teledermatology fellowships are also emerging at programs including University of Pittsburgh. We imagine that one day every patient will have had some interaction with a TD platform and it is important that new physicians are well trained in this method of communication.

We also recommend that physicians start encouraging their patients to take more pictures and use online patient portals. The newest generation of patients and providers has been raised in an era of smartphones with instant access to information via the internet. Aside from providing internet access, smartphones allow for the potential to store large amounts of data. In dermatology, often the most valuable mobile application a patient can have is their camera roll—having the ability to look at old pictures and assess how a lesion has evolved is priceless. Newer mobile applications have been designed specifically for dermatologic purposes such as tracking moles and are beneficial because they provide for more accountability and direct patient education and communication [5]. However, commercially available non-FDA cleared devices and

apps could be potential health hazards. Patients should not rely on a negative diagnosis from a self-diagnosing app to avoid late detection of melanomas or other skin malignancies.

Dermatology practices should be utilizing TD in order to see more patients, especially those patients who need more frequent follow up. Teledermatology allows patients to be seen in a more timely fashion and prevents unnecessary prolongation of disease courses. Patients who are otherwise unable to see a specialist now have access to a dermatologist's assessment and recommendations whether through consultations with a PCP or direct tele-appointments. Ultimately, to implement TD in a new practice we have to ensure that there are enough dermatologists to see an increased patient load. If currently practicing dermatologists are now expected to take on additional TD patients, we need to decide how to fit these patients into their schedule. Should they be seen on the regular schedule or after the workday has ended? How much time should be allotted per patient? Should there be a single doctor designated for TD patients only? As we are already in the midst of a dermatologist shortage these are important factors to consider.

Technology modalities aimed at decreasing face-to-face time also have inherent problems such as the inability to palpate lesions, magnify lesions, or closely evaluate both the lesions and surrounding skin under different lighting set ups. It may hinder the trainees' ability to conduct proper and comprehensive physical examinations and could impact patient-physician relationship. The face-to-face examination by a dermatologist is still the gold standard and should be used to confirm smartphone results. Unfortunately, the ability to use TD is limited by the difficulty in obtaining timely reimbursement. Some private mobile applications require an initial payment to use their service. However, this model is likely not practical when TD is used within a larger health network. Once this issue has been resolved, we imagine dermatologists will begin to advocate more for TD. At the time of writing, TD via live interactive consultations has been an effective substitute for many patients with dermatologic problems [82].

Conclusion

Developments in the field of digital dermatology are occurring so quickly that any review will be out of date by the time of publication. Teledermatology has the potential to expand the field of dermatology beyond the four walls of an examination room, and we believe that the future of dermatology will become heavily dependent on TD.

Potential conflicts of interest

Dr. Steven Feldman has received research, speaking and/or consulting support from a variety of companies including Galderma, GSK/Stiefel, Almirall, Leo Pharma, Boehringer Ingelheim, Mylan, Celgene, Pfizer, Valeant, Abbvie, Samsung, Janssen, Lilly, Menlo, Merck, Novartis, Regeneron, Sanofi, Novan, Qurient, National Biological Corporation, Caremark, Advance Medical, Sun Pharma, Suncare Research, Informa, UpToDate and National Psoriasis Foundation. He is founder and majority owner of www.DrScore.com and founder and part owner of Causa Research, a company dedicated to enhancing patients' adherence to treatment. Dr. Glines, Dr. Akkurt, Wasim Haidari, and Leena Ramani have no conflicts to disclose.

References

1. Coates SJ, Kvedar J, Granstein RD. Teledermatology: from historical perspective to emerging techniques of the modern era: part II: Emerging technologies in teledermatology, limitations and future directions. *J Am Acad Dermatol*. 2015;72:577-86; quiz 87-8. [PMID: 25773408].
2. Prado G, Kovarik C. Cutting edge technology in dermatology: virtual reality and artificial intelligence. *Cutis*. 2018;101:236-7. [PMID: 29763481].
3. Kunde L, McMeniman E, Parker M. Clinical photography in dermatology: ethical and medico-legal considerations in the age of digital and smartphone technology. *Australas J Dermatol*. 2013;54:192-7. [PMID: 23713892].
4. Hanna MG, Parwani AV, Pantanowitz L, Punjabi V, Singh R. Smartphone applications: A contemporary resource for

dermatopathology. *J Pathol Inform*. 2015;6:44. [PMID: 26284155].
5. Moreno-Ramirez D, Argenziano G. Teledermatology and Mobile Applications in the Management of Patients with Skin Lesions. *Acta Derm Venereol*. 2017;218:31-35. [PMID: 28676881].
6. Hamilton PW, Wang Y, McCullough SJ. Virtual microscopy and digital pathology in training and education. *APMIS*. 2012;120:305-15. [PMID: 22429213].
7. Bronfenbrener R. Learning dermatopathology in the digital age. *Cutis*. 2014;94:E22-4. [PMID: 25372265].
8. Brick KE, Sluzevich JC, Cappel MA, et al. Comparison of virtual microscopy and glass slide microscopy among dermatology residents during a simulated in-training examination. *Journal of cutaneous pathology*. 2013;40(9):807-11. [PMID: 23808673]. [doi: 10.1111/cup.12189].
9. Berger WA, Townsend Kraft M, Murphy MJ, Elaba Z. Randomized comparison of virtual microscopy and glass microscopy among dermatology and pathology residents during a simulated in-training examination. *J Cutan Pathol*. 2017;44:409-10. [PMID: 28150326].
10. Boyers LN, Schultz A, Baceviciene R, et al. Teledermatology as an educational tool for teaching dermatology to residents and medical students. *Telemed J E Health*. 2015;21:312-4. [PMID: 25635528].
11. Patel J, Parr K, Buehler-Bota T, Hood AF. Integrating Outpatient Teledermatology Education Into the Dermatology Resident Curriculum. *J Grad Med Educ*. 2016;8:468-9. [PMID: 27413472].
12. Nelson CA, Wanat KA, Roth RR, et al. Teledermatology as pedagogy: diagnostic and management concordance between resident and attending dermatologists. *J Am Acad Dermatol*. 2015;72:555-7. [PMID: 25687312].
13. Xu X, Posadzki PP, Lee GE, Car J, Smith HE. Digital Education for Health Professions in the Field of Dermatology: A Systematic Review by Digital Health Education Collaboration. *Acta Derm Venereol*. 2019;99:133-8. [PMID: 30320871].
14. DeLeo VA. Digital revolution: dermatology is on the edge. *Cutis*. 2019;103:7. [PMID: 30758336].
15. Wanat KA, Newman S, Finney KM, Kovarik CL, Lee I. Teledermatology Education: Current Use of Teledermatology in US Residency Programs. *J Grad Med Educ*. 2016;8:286-7. [PMID: 27168912].
16. Lami M, Malabanan K, McAuliffe O. Teledermatology in medical education - a 'rash' decision? *Med Educ Online*. 2015;20:30576. [PMID: 26680030].
17. George DR, Dellasega C. Use of social media in graduate-level medical humanities education: two pilot studies from Penn State College of Medicine. *Med Teach*. 2011;33:e429-34. [PMID: 21774639].
18. Shahriari N, Grant-Kels J, Murphy MJ. Dermatopathology education in the era of modern technology. *J Cutan Pathol*. 2017;44:763-71. [PMID: 28612388].
19. Ko LN, Rana J, Burgin S. Incorporating social media into dermatologic education. *Dermatol Online J*. 2017;23(10). [PMID: 29469778].
20. Cheston CC, Flickinger TE, Chisolm MS. Social media use in medical education: a systematic review. *Acad Med*. 2013;88:893-901. [PMID: 23619071].
21. Kunzler E, Graham J, Mostow E. Motivating medical students by utilizing dermatology-oriented online quizzes. *Dermatol Online J*. 2016;22. [PMID: 27617612].
22. Meeks NM, McGuire AL, Carroll BT. Electronic collaboration in dermatology resident training through social networking. *Cutis*. 2017;99:253-8. [PMID: 28492592].
23. Nadeau MT, Tysinger J, Wiemers M. A case-based approach for teaching professionalism to residents with online discussions. *J Adv Med Educ Prof*. 2016;4:1-7. [PMID: 26793719].
24. Shi Y, Manco M, Moyal D, et al. Soft, stretchable, epidermal sensor with integrated electronics and photochemistry for measuring personal UV exposures. *PloS One*. 2018;13:e0190233. [PMID: 29293664].
25. Seite S, Fourtanier A, Moyal D, Young AR. Photodamage to human skin by suberythemal exposure to solar ultraviolet radiation can be attenuated by sunscreens: a review. *Br J Dermatol*. 2010;163:903-14. [PMID: 20977441].
26. Lee JW, Xu R, Lee S, et al. Soft, thin skin-mounted power management systems and their use in wireless thermography. *Proc Natl Acad Sci of the USA*. 2016;113:6131-6. [PMID: 27185907].
27. Dey S, Sahoo S, Agrawal H, et al. Personalized cumulative UV tracking on mobiles & wearables. *Conf Proc IEEE Eng Med Biol*. 2017;2017:2341-4. [PMID: 29060367].
28. Hussain MS, Cripwell L, Berkovsky S, Freyne J. Promoting UV Exposure Awareness with Persuasive, Wearable Technologies. *Stud Health Technol Inform*. 2016;227:48-54. [PMID: 27440288].
29. Chee SN, Lowe P, Lim A. Smartphone patient monitoring post-laser resurfacing. *Australas J Dermatol*. 2017;58:e216-e22. [PMID: 27282697].
30. Fruhauf J, Krock S, Quehenberger F, et al. Mobile teledermatology helping patients control high-need acne: a randomized controlled trial. *J Eur Acad Dermatol Venereol*. 2015;29:919-24. [PMID: 25258175].
31. Koller S, Hofmann-Wellenhof R, Hayn D, Weger W, Kastner P, Schreier G, Salmhofer W. Teledermatological monitoring of psoriasis patients on biologic therapy. *Acta Derm Venereol*. 2011;91:680-5. [PMID: 21879250].
32. Bashshur RL, Shannon GW, Tejasvi T, Kvedar JC, Gates M. The Empirical Foundations of Teledermatology: A Review of the Research Evidence. *Telemed J E Health*. 2015;21:953-79. [PMID: 26394022].
33. Berk-Krauss J, Polsky D, Stein JA. Mole Mapping for Management of Pigmented Skin Lesions. *Dermatol Clin*. 2017;35:439-45. [PMID: 28886799].
34. Lee KJ, Finnane A, Soyer HP. Recent trends in teledermatology and teledermoscopy. *Dermatol Pract & Concepl*. 2018;8:214-23. [PMID: 30116667].
35. Wu X, Oliveria SA, Yagerman S, et al. Feasibility and Efficacy of Patient-Initiated Mobile Teledermoscopy for Short-term Monitoring of Clinically Atypical Nevi. *JAMA Dermatol*. 2015;151:489-96. [PMID: 25629626].
36. Chen J, Cade JE, Allman-Farinelli M. The Most Popular Smartphone Apps for Weight Loss: A Quality Assessment. *JMIR Mhealth Uhealth*. 2015;3:e104. [PMID: 26678569].
37. Fabbrocini G, De Vita V, Pastore F, et al. Teledermatology: from prevention to diagnosis of nonmelanoma and melanoma skin cancer. *Int J Telemed Appl*. 2011;2011:125762. [PMID: 21776252].
38. Hibler BP, Qi Q, Rossi AM. Current state of imaging in dermatology. *Semin Cutan Med Surg*. 2016;35:2-8. [PMID: 26963110].
39. Fogel AL, Sarin K. The digital age of melanoma management: detection and diagnostics. *Melanoma Manag*. 2015;2:383-91. [PMID: 30190865].
40. Wolf JA, Moreau JF, Patton TJ, Winger DG, Ferris LK. Prevalence and impact of health-related internet and smartphone use among dermatology patients. *Cutis*. 2015;95:323-8. [PMID: 26125208].
41. Maier T, Kulichova D, Schotten K, et al. Accuracy of a smartphone application using fractal image analysis of pigmented moles compared to clinical diagnosis and histological result. *J Eur Acad Dermatol Venereol*. 2015;29:663-7. [PMID: 25087492].

42. Chuchu N, Dinnes J, Takwoingi Y, et al. Teledermatology for diagnosing skin cancer in adults. *Cochrane Database Syst Rev*. 2018;12:Cd013193. [PMID: 30521686].
43. Wang M, Gendreau JL, Gemelas J, et al. Capulong D, Lau C, Mata-Diaz S, Bratten DM, Dougall B, Markham C, Raugi GJ. Diagnosis and Management of Malignant Melanoma in Store-and-Forward Teledermatology. *Telemed J E Health*. 2017;23:877-80. [PMID: 28498031].
44. Creighton-Smith M, Murgia RD, Konnikov N, Dornelles A, Garber C, Nguyen BT. Incidence of melanoma and keratinocytic carcinomas in patients evaluated by store-and-forward teledermatology versus. dermatology clinic. *Int J Dermatol*. 2017;56:1026-31. [PMID: 28631824].
45. Farberg AS, Glazer AM, Winkelmann RR, Tucker N, White R, Rigel DS. Enhanced melanoma diagnosis with multispectral digital skin lesion analysis. *Cutis*. 2018;101:338-40. [PMID: 29894523].
46. Finnane A, Dallest K, Janda M, Soyer HP. Teledermatology for the Diagnosis and Management of Skin Cancer: A Systematic Review. *JAMA Dermatol*. 2017;153:319-27. [PMID: 27926766].
47. Carter ZA, Goldman S, Anderson K, et al. Creation of an Internal Teledermatology Store-and-Forward System in an Existing Electronic Health Record: A Pilot Study in a Safety-Net Public Health and Hospital System. *JAMA Dermatol*. 2017;153:644-50. [PMID: 28423156].
48. Greis C, Meier Zurcher C, Djamei V, Moser A, Lautenschlager S, Navarini AA. Unmet digital health service needs in dermatology patients. *J Dermatolog Treat*. 2018;29:643-7. [PMID: 29455570].
49. Armstrong AW, Kwong MW, Ledo L, Nesbitt TS, Shewry SL. Practice models and challenges in teledermatology: a study of collective experiences from teledermatologists. *PloS one*. 2011;6:e28687. [PMID: 22194887].
50. Whited JD. Economic analysis of telemedicine and the teledermatology paradigm. *Telemed J E Health*. 2010;16:223-8. [PMID: 20136558].
51. Kochmann M, Locatis C. Direct to Consumer Mobile Teledermatology Apps: An Exploratory Study. *Telemed J E Health*. 2016;22:689-93. [PMID: 26960113].
52. Gliklich RE, Bibeau K, Eisenberg F, et al. AHRQ Methods for Effective Health Care. In: Outcome Measures Framework: Information Model Report: Registry of Patient Registries. Rockville (MD): Agency for Healthcare Research and Quality (US); 2018.
53. Hinojosa JA, Pandya AG. The Importance of Patient Registries in Skin of Color. *J Investig Dermatol Symp Proc*. 2017;18:S31-s3. [PMID: 28941490].
54. DiMarco G, Hill D, Feldman SR. Review of patient registries in dermatology. *J Am Acad Dermatol*. 2016;75:824-9. [PMID: 27095504].
55. Rustenbach SJ, Heyer K, Reppenhagen K, Augustin M. [Registry research in dermatology]. *Hautarzt*. 2011;62:189-95. [PMID: 21369966].
56. Feldman SR, Camacho FT, Krejci-Manwaring J, et al. Adherence to topical therapy increases around the time of office visits. *J Am Acad of Dermatol*. 2007;57:81-3. [PMID: 17498841].
57. Griffin A, Skinner A, Thornhill J, Weinberger M. Patient Portals: Who uses them? What features do they use? And do they reduce hospital readmissions? *Appl Clin Inform*. 2016;7:489-501. [PMID: 27437056].
58. Giesey R, Mostow E, Lloyd J. Digital strategies for dermatology patient education. *Cutis*. 2018;101:209-10. [PMID: 29718025].
59. Storm A, Benfeldt E, Andersen SE, Andersen J. Basic drug information given by physicians is deficient, and patients' knowledge low. *J Dermatolog Treat*. 2009;20:190-3. [PMID: 19040185].
60. Masud A, Shafi S, Rao BK. Mobile medical apps for patient education: a graded review of available dermatology apps. *Cutis*. 2018;101:141-4. [PMID: 29554157].
61. Armstrong AW, Watson AJ, Makredes M, et al. Text-message reminders to improve sunscreen use: a randomized, controlled trial using electronic monitoring. *Arch Dermatol*. 2009;145:1230-6. [PMID: 19917951].
62. Balato N, Megna M, Di Costanzo L, et al. Educational and motivational support service: a pilot study for mobile-phone-based interventions in patients with psoriasis. *Br J Dermatol*. 2013;168:201-5. [PMID: 23240729].
63. Yentzer BA, Wood AA, Sagransky MJ, et al. An Internet-based survey and improvement of acne treatment outcomes. *Arch Dermatol*. 2011;147:1223-4. [PMID: 22006146].
64. Ariens LF, Schussler-Raymakers FM, Frima C, et al. Barriers and Facilitators to eHealth Use in Daily Practice: Perspectives of Patients and Professionals in Dermatology. *J Med Internet Res*. 2017;19:e300. [PMID: 28874336].
65. Williams T, May C, Esmail A, et al. Patient satisfaction with store-and-forward teledermatology. *J Telemed Telecare*. 2001;7 Suppl 1:45-6. [PMID: 11576488].
66. Lim D, Oakley AM, Rademaker M. Better, sooner, more convenient: a successful teledermoscopy service. *Australas J Dermatol*. 2012;53:22-5. [PMID: 22309326].
67. Boyce Z, Gilmore S, Xu C, Soyer HP. The Remote Assessment of Melanocytic Skin Lesions: a Viable Alternative to Face-to-Face Consultation. *Dermatology*. 2011;223:244-50. [PMID: 22095005].
68. Fiks AG, Fleisher L, Berrigan L, et al. Usability, Acceptability, and Impact of a Pediatric Teledermatology Mobile Health Application. *Telemed J E Health*. 2018;24:236-45. [PMID: 28731848].
69. Spinks J, Janda M, Soyer HP, Whitty JA. Consumer preferences for teledermoscopy screening to detect melanoma early. *J Telemed Telecare*. 2016;22:39-46. [PMID: 26026184].
70. Mounessa JS, Chapman S, Braunberger T, et al. A systematic review of satisfaction with teledermatology. *J Telemed Telecare*. 2018;24:263-70. [PMID: 28350281].
71. Marchell R, Locatis C, Burgess G, et al. Patient and Provider Satisfaction with Teledermatology. *Telemed J E Health*. 2017;23:684-90. [PMID: 28375822].
72. Yang YT, Silverman RD. Mobile health applications: the patchwork of legal and liability issues suggests strategies to improve oversight. *Health Aff (Project Hope)*. 2014;33:222-7. [PMID: 24493764].
73. McKoy K, Antoniotti NM, Armstrong A, et al. Practice Guidelines for Teledermatology. *Telemed J E Health*. 2016;22:981-90. [PMID: 27690203].
74. Tensen E, van der Heijden JP, Jaspers MW, Witkamp L. Two Decades of Teledermatology: Current Status and Integration in National Healthcare Systems. *Curr Dermatol Rep*. 2016;5:96-104. [PMID: 27182461].
75. Harting MT, DeWees JM, Vela KM, Khirallah RT. Medical photography: current technology, evolving issues and legal perspectives. *Int J Clin Pract*. 2015;69:401-9. [PMID: 25708063].
76. Abbott LM, Magnusson RS, Gibbs E, Smith SD. Smartphone use in dermatology for clinical photography and consultation: Current practice and the law. *Australas J Dermatol*. 2018;59:101-7. [PMID: 28247404].
77. Rimoin L, Haberle S, DeLong Aspey L, et al. Informed Consent, Use, and Storage of Digital Photography Among Mohs Surgeons in the United States. *Dermatol Surg*. 2016;42:305-9. [PMID: 26863597].
78. Rosen AR, Littman-Quinn R, Kovarik CL, Lipoff JB. Landscape of business models in teledermatology. *Cutis*. 2016;97:302-4. [PMID: 27163914].

79. Armstrong AW, Idriss NZ, Kim RH. Effects of video-based, online education on behavioral and knowledge outcomes in sunscreen use: a randomized controlled trial. *Patient Educ Couns.* 2011;83:273-7. [PMID: 20570081].
80. Campagna M, Naka F, Lu J. Teledermatology: An updated overview of clinical applications and reimbursement policies. *Int J Womens Dermatol.* 2017;3:176-9. [PMID: 28831431].
81. Ratner D, Thomas CO, Bickers D. The uses of digital photography in dermatology. *J Am Acad Dermatol.* 1999;41:749-56. [PMID: 10534639].
82. Perkins S, Cohen JM, Nelson CA, Bunick CG. Teledermatology in the Era of COVID-19: Experience of an Academic Department of Dermatology. *J Am Acad Dermatol.* 2020;83:e43-e4. [PMID: 32305442].

Table 1. *Studies assessing teledermatology for education.*

Title	Authors	Study Type	Objective	Population	Conclusions
Comparison of virtual microscopy and glass slide microscopy among dermatology residents during a simulated in-training examination [8]	Brick KE, Sluzevich JC, et al.	Survey	Evaluate diagnostic accuracy and attitudes between virtual microscopy and traditional glass slide microscopy among dermatology residents	Dermatology residents and fellows	Overall, diagnostic accuracy was better with glass slides than virtual slides (P=0.01) There was no overall personal preference for glass slide vs. virtual microscopy
Randomized comparison of virtual microscopy and glass microscopy among dermatology and pathology residents during a simulated in-training examination [9]	Berger WA, Townsend Kraft M, et al.	Randomized comparison	Determine whether examination scores of residents would be equivalent when tested using the two image formats; the opinions of examinees regarding the two techniques were assessed	Dermatology residents and fellows	The ability of residents to accurately diagnose dermatopathology cases was similar when tested using virtual microscopy and glass slide microscopy, despite their overall preference for the latter
Teledermatology as an educational tool for teaching dermatology to residents and medical students [10]	Boyers LN, Schultz A, et al.	Survey	To assess dermatology residents' and medical students' perceptions of TD and its usefulness in teaching six core clinical competencies	Dermatology residents; Medical students	Both residents (79%) and medical students (88%) "strongly agree" or "agree" that TD is an important educational tool TD is valued as a teaching tool for dermatology in the areas of patient care, medical knowledge, practice-based learning and improvement, and systems-based practice

Teledermatology as pedagogy: diagnostic and management concordance between resident and attending dermatologists [12]	Caroline A. Nelson, Karolyn A. Wanat, et al.	Prospective study	Assess diagnostic and management concordance between resident and attending dermatologists responding to store-and-forward teledermatology consults submitted by primary care providers	Dermatology residents and attendings	Diagnoses and management plans between resident and attending dermatologists were fully concordant for 53% and 65% of dermatologic conditions, respectively Our data revealed at least partial diagnostic and management discordance between resident and attending dermatologists for 47% and 35% of dermatologic conditions, respectively
Digital Education for Health Professions in the Field of Dermatology: A Systematic Review by Digital Health Education Collaboration [13]	Xu X, Posadzki PP, et al.	Cochrane review approach	Assess the evidence for the effectiveness of health professions' digital education in dermatology to improve knowledge, skills, attitudes and satisfaction	Health professionals	The main learning outcomes were comparable in terms of knowledge improvement, skills enhancement and satisfaction suggesting the potential of digital health education to be used as a complementary or alternative method to traditional learning in dermatology
Teledermatology Education: Current Use of Teledermatology in US Residency Programs [15]	Wanat KA, Newman S, et al.	Descriptive survey	Better understand the current involvement and potential interest in telemedicine in dermatology training programs	Dermatology residency programs	Of the 72 responders, 34 (47%) programs were using telemedicine as part of their residency curriculum with store and forward technology being the most commonly used (85%), followed by live interactive (35%) or a combination of the 2 methods The survey results identify an educational gap in telemedicine training for dermatology residents
Electronic collaboration in dermatology resident training through social networking [22]	Meeks NM, McGuire A, et al.	Survey	Gain a better understanding of how they currently provide education and what online resources and social networking sites they currently use or would be willing to use	Dermatology residents and faculty	A majority of faculty and residents stated that they use online educational materials as supplements to traditional classroom lecture and print materials (81% vs 86%); however, almost twice as many residents stated that online educational materials were essential to their current study routines compared to faculty (39% vs 21%)