Diplomarbeit

THE USE OF MOBILE PHONES FOR SKIN TUMOR SCREENING

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Graz, Datum ………………………….. (Unterschrift)

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Abstract

Background: Telemedicine is an aspiring field in medicine and is often used as an umbrella term that encompasses a wide range of medical activities involving distance. It can be described as the delivery of health services via remote communications and includes consultative, diagnostic and therapeutic services. Applied in an appropriate context telemedicine may potentially improve the quality and accessibility of medical care. Teledermatology is one of many subcategories in telemedicine.
Mobile telemedicine is characterized by the use of portable mobile equipment such as mobile phones and personal digital assistants (PDAs).

Objective: A clinical study was designed in order to investigate the feasibility of skin tumor screening using camera mobile phones.

Design: 100 patients with a total number of 119 skin tumors were selected from the general outpatient clinic at the Department of Dermatology, Medical University of Graz (Austria). All lesions were photographed with the built-in camera of a modern mobile phone. In each case a close-up clinical image and a dermoscopic image applying the cellular phone on a pocket dermoscopy device were obtained. Images of the cases (clinical images separately from dermoscopic images) were sent to a teleconsultant for evaluation via a virtual private network (www. dermahandy.net/default.asp) using a store-and-forward system.

Outcome measures: Diagnostic concordance between face-to-face diagnosis and telediagnosis; Accuracy of telediagnosis using clinical images vs. dermoscopic images; concordance with histopathological diagnosis

Results: The average degree of concordance between face-to-face diagnoses and telediagnoses was 86.3% for the clinical images and 76.6% for the dermoscopic images.

Conclusion: Telediagnosis of dermatologic images made by a mobile phone provides good diagnostic accuracy, with clinical images providing a higher concordance of diagnoses than corresponding dermoscopic images.

Zusammenfassung

Hintergrund: Telemedizin ist definiert als die Übertragung medizinischer Daten mittels Telekommunikationstechnologien zum Zweck von Diagnostik, Therapie und Lehre.
Der Fortschritt in der Telekommunikation und digitalen Bildverarbeitung der letzten Jahre hat zu großen Entwicklungen in der Telemedizin geführt. Teledermatologie stellt eine Subentität der Telemedizin dar. Mobile Telemedizin ist charakterisiert durch die Verwendung portabler Kleingeräte, welche Möglichkeiten der Bilderstellung, Datenerfassung und -übertragung ineinander vereinen, wie etwa Mobiltelefone und PDAs

Zielsetzung: Eine klinische Studie wurde entworfen, um die Genauigkeit der Hauttumordiagnostik unter Verwendung eines Mobiltelefones mit integrierter Kamera zu evaluieren.

Aufbau: Für die Studie wurden 100 PatientInnen mit insgesamt 119 tumorösen Hautläsionen ausgewählt.Mit der Kamera eines modernen Mobiltelefones wurden sowohl klinische als auch auflichtmikroskopische Bilder angefertigt, für letztere wurde ein tragbares Auflichtmikroskop zwischen der Läsion und der Kameralinse platziert.
Die jeweiligen Bilder wurden an einen Teledermatologen zwecks Fernbefundung weitergeleitet, wobei die auflichtmikroskopischen Aufnahmen zeitversetzt zu den klinischen Aufnahmen gesendet wurden, um eine unabhängige Befundung zu gewährleisten. Bei der hierfür verwendeten Plattform handelt es sich um ein privates Netzwerk, basierend auf einem store-and-forward System (www. dermahandy.net/default.asp).

Zielgrößen: Untersucht wurde die Übereinstimmung der Ferndiagnosen mit den Diagnosen, die vor Ort gestellt wurden. In weiterer Folge wurde jeweils auch die Konkordanz mit histologischen Befunden bestimmt.
Ergebnisse: Die durchschnittliche Übereinstimmung lag bei 86.3 % bei den klinischen Telediagnosen und 76.6 % bei den auflichtmikroskopischen.

Schlussfolgerung: Telediagnostik von dermatologischen Bildern, die mit einem Mobiltelefon aufgenommen wurden bieten hohe diagnostische Genauigkeit, wobei diese bei klinischen Aufnahmen höher ist als bei auflichtmikroskopischen.

Table of contents

Abbreviations vi

1. Telemedicine 1

1.1 General introduction 1

1.2 Definitions 2

1.3 Historical perspective 4

1.4 Modes of data transmission 9

1.4.1 Store and forward (SAF) systems *9*

1.4.2 Real-time Interactive Telemedicine *9*

1.4.3 Store and forward versus Real time techniques *10*

1.5 Mobile telemedicine 11

1.6 Fields of application 13

1.7 Tele-education 17

1.8 Telemedicine- fear and loathing 19

1.9 Legal and ethical aspects 20

1.10 Successful implementation of telemedical appliances 22

2. Teledermatology 24

2.1 Mobile teledermatology 26

3. A Clinical study 27

3.1 Material and methods 28

3.1.2 Mobile phone *30*

3.1.3 Dermoscope *31*

3.1.4 Data transmission *32*

3.1.5 Website *32*

3.1.6 Tele-evaluation procedures *324*

4. Results 36

4.1 First step: Tele-evaluation of clinical images 38

4.1.1 Agreement between telediagnosis of clinical images and FTF-diagnosis *38*

4.1.2 Agreement between telediagnosis of clinical images and histology *38*

4.2 Second step: Tele-evaluation of dermoscopic images 40

4.2.1 Agreement between telediagnosis of dermoscopic images and FTF-diagnosis *41*

4.2.2 Agreement between telediagnosis of dermoscopic images and histology *41*

4.3 Third step: Tele-evaluation of clinical images in combination with dermoscopic images 42

4.4 Case studies 44

5. Discussion 45

5.1 User friendliness 47

5.2 Data transmission 48

6. Conclusion 49

References 51

Abbreviations

ATM: *Asynchronous Transfer Mode,* a telecommunications protocol used in networking, a strategy first developed in the nineteen eighties to transport real-time video and audio as well as image files, text and email

Bluetooth: system for wireless data transmission between mobile phones, laptops, personal computers, printers, digital cameras, and video game consoles over a secure, globally unlicensed short-range radio frequency

FTF diagnosis: *face-to-face diagnosis,* diagnosis made on-site having direct contact with the patient

DICOM: *Digital Imaging and Communications in Medicine,* a standard for handling, storing, printing, and transmitting information in medical imaging including a file format definition and a network communications protocol

GSM: *Global System for Mobile Communication,* popular data communication system for mobile phones

GPRS: *General Packet Radio Service,* Mobile Data Service for the transmission of data via packets (=discrete blocks of data)

HTML: *Hypertext Markup Language,* one of the protocols of the World Wide Web; a set of annotations to text that describe how it is to be structured, laid out, or formatted

HON: *Health On the Net Foundation,* a Swiss non-governmental organization providing online medical and health information

ISDN: *Integrated Services Digital Network,* a circuit-switched telephone network system designed to allow digital transmission of voice and data

JPEG: *Joint Photographic Experts Group,* commonly used method of compression for photographic images
LAN: *Local Area Network,* computer network covering a small geographic area, like a home, office, or group of buildings

MEDLINE (Medical Literature Analysis and Retrieval System Online): literature database of life sciences and biomedical information compiled by the U.S. National Library of Medicine (NLM), freely available and searchable through *PubMed*

MMS: *Multimedia Messaging Service,* a standard for telephone messaging systems that allows sending messages that include multimedia objects (images, audio, video, rich text)

PACS: *Picture Archiving and Communication System,* digital medical image management, communication, review and distribution system widely used in hospitals, clinics and imaging centers

PDA: *Personal Digital Assistant,* an electronic device which can include some of the functionality of a computer, a cell phone, a music player, and a camera

Pixel: a single point in a graphic image

PubMed: free search engine for accessing the *MEDLINE* database of citations and abstracts of biomedical research articles

SAF: *Store-and-forward,* telecommunications technique in which information is sent to an intermediate station where it is kept and sent at a later time to the final destination or to another intermediate station

UMTS: *Universal Mobile Telecommunication System,* data transmission standard for mobile and satellite transmission, successor to GSM

URL: *Uniform Resource Locator,* address that defines the route to a file on an Internet server (web server, FTP server, mail server, etc.)

USB: *Universal Serial Bus,* widely used hardware interface for attaching peripheral devices for data transmission/exchange

WAP: *Wireless Application Protocol,* standard for providing cell phones, pagers and other handheld devices with secure access to email and text-based Web pages

WLAN: *Wireless Local Area Network,* the linking of two or more computers without using wires

WML: *Wireless Markup Language,* Markup language intended for devices that implement the Wireless Application Protocol (WAP) specification, such as mobile phones

WWW: *World Wide Web,* system of interlinked hypertext documents accessed via the Internet that may contain text, images, videos, and other multimedia

1. Telemedicine

1.1 General introduction

The word telemedicine derives from the Greek word "tele" meaning remote, thus telemedicine can be described as the practice of medicine from a distance.
What is nowadays subsumed under the banner of telemedicine covers a much larger range and is not just confined to diagnostic procedures.

The common thread in telemedicine is a client of some sort (i.e. a patient) obtaining an opinion from an expert when the two are separated in space, in time, or both [1]. Telemedicine has obvious advantages in remote or rural areas with only few specialists as it can enable a well- founded diagnosis by an expert even when a face-to-face diagnosis is not possible.
Telemedicine could permit decentralization by enhancing communication up and down the health pyramid. Accordingly, work previously done in particularly specialized domains could partially be delegated to the primary care sector and specialist hospitals could offer opportunities to export their skills for money [2].

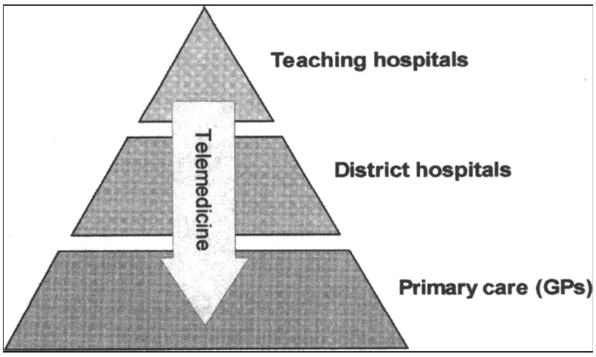


Figure1.1. Telemedicine as a technique for decentralization, improving communication down the health care pyramid
Source: Wootton R. [2]

The increased access to services, i.e. by bringing expertise to a patient in areas where there is no expert available for face-to-face consultation, is just one of many aspects underlining the advantages of telemedicine.
Nevertheless, there are potential drawbacks that have to be considered thoroughly before implementing a new telemedicine application: alongside ethical and legal aspects, the costs

of telemedicine should be compared with the costs of traditional practice [2,3].Moreover, many specialties in Medicine have developed advanced telemedicine techniques for their particular fields, as will be elaborated in the course of this thesis (see also chapter 1.6).

1.2 Definitions

Definitions of telemedicine and related key words such as telehealth, e-health (also written eHealth) or telecare can be found in legitimate online dictionaries (e.g. Wikipedia) or online medical dictionaries such as Medline.

Moreover, they are discussed in scholarly literature and literature reviews. But definitions may vary or overlap and distinctions may be ambiguous.

Telemedicine, telehealth and e-health are terms that are often used interchangeably. However, there are subtle differences in their definitions.

Many definitions are confusing as they try to be all-embracing and have little relation to what they originally intended to describe.

Instead of adding to the possible confusion by creating yet another new set of definitions, the terms used in this thesis accord to certain well-established definitions listed subsequently.

Telemedicine is often used as an umbrella term tantamount to E-health.
However, *telemedicine in the stricter sense* can be defined as the use of telecommunication to provide diagnostic and therapeutic medical information between patient and doctor without either of them having to travel [4].
Telehealth (excerpted from www.wikipedia.org) "is an expansion of telemedicine, and unlike telemedicine (which more narrowly focuses on the curative aspect) it encompasses preventive, promotive *and* curative aspects." Communications and information technology is used to deliver health and health care services and information over large and small distances.

E-health goes way beyond both telemedicine and telehealth and can be described as an aspiring field in the intersection of medical informatics, public health and business [5]. The precise meaning of the term varies with the context it is used in [6].

The term can encompass a range of services that are at the edge of medicine/health care and information technology and covers any form of health care practice that is supported by electronic processes and communication.

Telecare can be described as the use of information and communication technologies to transfer medical information for the delivery of clinical services to patients in their place of domicile [7].

Particular issues such as "tele-education" and "e-learning" in a medical context will be addressed further (see chapter 1.7)

1.3 Historical perspective

It is unknown when telecommunications were first implemented in health care [8].
The concept may date back centuries, with historical accomplishments such as the invention of the telephone, or later on the introduction of video conferencing, setting milestones for telemedicine as we know it today.
Early articles dealing with the concept of telemedicine contain expressions or phrases such as *telognosis* or “diagnosis by television”. The earliest such reference dates from 1950 [9]. However, the designated term “telemedicine” was not seen in Medical literature until 1974 [10].

Current telemedicine applications have three different origins; developments in the manned space-flight program of NASA (National Aeronautics and Space Administration) was the first such example (note: in addition to the activities in telemedicine associated with human space flight, NASA has also been involved in many demonstrations of terrestrial telemedicine applications that will be mentioned subsequently).
Furthermore, the practicability of telemedicine nowadays also stems from the pioneering efforts of a few physicians using off-the-shelf commercial equipment.
The third evolutionary cornerstone attributes to efforts made by military institutions that contributed to the evolution of mobile health and telemedicine in disasters.

NASA´s efforts started in the early 1960s when humans first started flying in space. Following the necessity to monitor or “telemeter” physiological parameters for the astronaut’s physicians on earth, NASA's scientists, engineers, and contractors developed sophisticated biomedical telemetry and telecommunications systems for biomedical applications [11].

NASA proved that an earth-bound physician could monitor the state of health of astronauts in space with the possibility of diagnosis and treatment in a situation where a face-to-face consultation is out of the question.
The acquirements made in the field of aeronautics brought into focus the parallel between the needs of an earth-bound physician trying to monitor, diagnose, and treat an astronaut in space, and the needs of equally earth-bound physicians trying to diagnose or treat a patient in a remote location.

Thus non-governmental institutions started to make use of these developments.
In 1964, the University of Nebraska at Omaha (Nebraska, USA) implemented a two-way link between the psychiatric institute and Norfolk State Hospital, more than 150 kilometers away. The link was used for education and for consultations between specialists and general practitioners [12].

The first complete telemedicine system linking paraprofessionals and physician- patient encounter settings was installed in 1967, linking the medical station at Boston's Logan Airport to Massachusetts General Hospital.
The Medical department was staffed by nurses twenty-four hours per day and the nurse-selected patients were evaluated by independent personnel and independent physician observers. A study and diagnosis of X-rays was readily performed. The study showed that telemedicine can improve the disposability of professional medical care [13].

Many telemedical programs were developed in rural areas, where medical staffing was a critical issue. One of the rural programs, amongst many others, is STARPAHC (Space Technology Applied to Rural Papago Advanced Health Care). The program ran from 1972- 1975 and delivered medical care to the Papago Indians in a mobile health unit (MHU) in a Reservation in Arizona.

Another major program, the “North-West Telemedicine Project” was conducted in Queensland/Australia in 1984 to test a government satellite communications network (the Q-Network).
A connection between five remote cities south of the golf of Carpentaria was established in order to provide health care to the people living there, two thirds of which were Aborigines or Torres Strait Islanders.
The hub of the network was the Mount Isa Base Hospital. All sites were supplied with a conference telephone, fax, and freeze-frame transceivers.[i]
Prior to this time, consults were conducted via telephone, radio, or by the Royal Flying Doctor Service [14].

[i] Freeze- frame television: Still images (the frames of the video) are transmitted sequentially at a rate far too slow to be perceived as continuous motion by human vision. Freeze-frame television has a lower bandwidth requirement than that of full-motion television and is therefore beneficial in less sophisticated satellite transmission.

After 1985, following the devastating earthquake in Mexico City, telecommunication technology finds use in yet another context: telemedicine in civilian disasters.
The NASA proffered and prioritized the use of their so called ATS-3 (Advanced Technology 3) communication satellite for the support of national as well as international rescue teams.
This constituted a vital link, seen as the earthquake disrupted nearly all land-based forms of communication in Mexico City with the exception of a few ham radio operations [15].

Another major earthquake in 1988 in Armenia entailed the foundation of the U.S.-U.S.S.R. **Space Bridge project**, a primary example of global telemedicine disaster assistance over time [16,17].

The Space Bridge Project linked several Armenian regional hospitals with four US Medical Centers (The Uniformed Services University of the Health Sciences, Bethesda, Maryland; Maryland Institute for Emergency Medical Services Systems, Baltimore, Maryland, The University of Texas Health Sciences Center, Houston, Texas; and LDS Hospital, Salt Lake City, Utah), providing consultations in several medical fields such as neurology, infectious diseases and general surgery.
Two-way interactive audio and unidirectional full-motion video transmissions from Armenia to the United States were used for transferring data. Over a 12-week period the medical care of 209 Armenian patients could be amplified by the Space Bridge program [18].
During the conduct of this telemedicine Spacebridge to Armenia, there was a terrible train accident in Ufa, Russia, causing a large number of casualties.
The Space Bridge was extended and a separate link permitted medical consultation for burn victims.
Slow-scan black and white video images were transmitted from Ufa to one of the Space Bridge sites in Armenia (Yerevan), which provided the satellite uplink[ii] and therefore the connection between Ufa and medical centers in the US [18,19].

Space Bridge is now called "Space Bridge to Russia" and employs multimedia, email, the World Wide Web, and interactive video conferencing.

[ii] An **uplink** (UL or U/L) is the portion of a communications link used for the transmission of signals from an Earth terminal to a satellite or to an airborne platform and is the inverse of a downlink.

Project physicians use a common web browser to consult on clinical cases aiming to support education as well as the evaluation of internet-based telemedicine infrastructures [20].

As mentioned above, the military also left its marks on the progress of telemedicine. During the late 1980s and early 1990s, technological progress provided the military with the ability to establish integrated health care delivery networks in many areas of the world. During the Persian war in 1991, advanced mobile health units (transportable modular army evacuation hospitals) equipped with computerized tomography scanners were implemented [21].
CT images were then transmitted via satellite and the international telephone network to Brooke Army Medical Center in San Antonio, Texas, for expert consultation.
Satellite teleradiology from Operation desert storm proved the value of teleradiology in combat situations and also showed that such systems can work under difficult climatic and geographic circumstances [21,22].

Operation Primetime, established in 1993, provided telemedicine support to medical units in Macedonia and Croatia.
Primetime II, an upgrade of the original operation, impressed with a thirty-fold increase in communication bandwidth and therefore an improved transmission of medical images [23].

T-1 asynchronous transfer mode (ATM) technology was used for several integration tests that included ultrasound with color Doppler at T-1 rates.
Primetime III was using even more sophisticated technological features that allowed military physicians to consult one-another via satellite using real-time voice and video conferencing. Primetime III was established in 1996 by the U.S. Department of Defense in the scope of setting up a medical network in Bosnia that connected army field physicians with physicians at five regional military medical centers in the United States (Washington, Texas, California, District of Columbia, and Hawaii).

For Primetime III the communication infrastructure changed from ATM to ISDN (integrated services digital network). The head office here for was situated in Landstuhl, Germany and further telemedicine nodes were installed at the combat support hospital in Taszar, Hungary, and the MASH (mobile army surgery hospital) unit in Tuzla, Bosnia. This connection to medical centers in different time zones facilitated twenty-four-seven specialist consultation and did not require extra medical staff at the telemedicine nodes outside Bosnia [23,24].

The areas of application pointed out are only a few out of a huge variety in the early development of telemedicine.

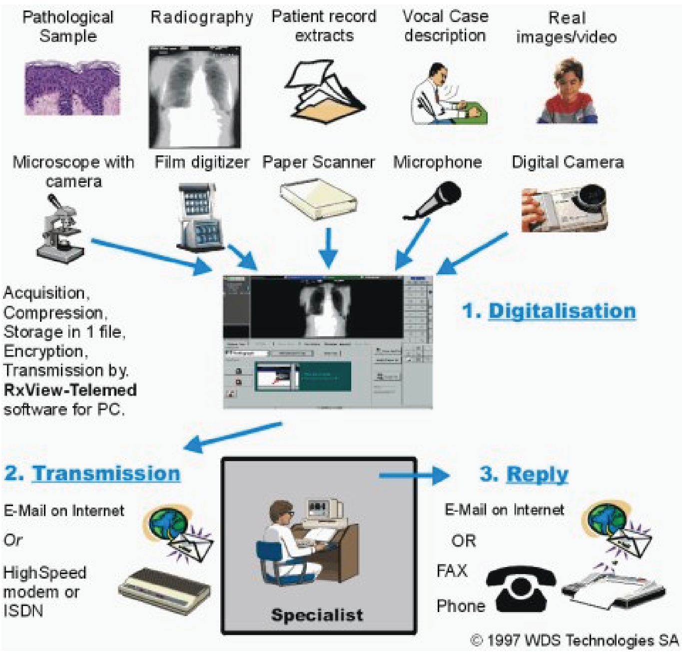
Over the decades, techniques and applications have become more and more sophisticated and the market is still vastly growing.

E- Health represents a highly heterogeneous field that is growing rapidly, which, amongst other things, may be put down to the ongoing technical advances and improvements of our times.

1.4 Modes of data transmission

1.4.1 Store-and-forward (SAF) systems

represent an asynchronous (time-independent), non-interactive form of telemedicine. Patient data such as clinical information, demographic details and digital images is captured and "stored" on the client computer; then, at a convenient time the information is transmitted to a referral center for future access by consultants.
The opinion of the specialist is then transmitted either by email, phone or fax.
Thus, participants are separated by time and space.



1.2.

1.4.2 Real-time interactive telemedicine

adheres to video conferencing equipment as the most common form of interaction. Audio-video signals facilitate an instantaneous consultation similar to face-to-face diagnosis. Participants are separated only by space, not by time.

A ***combination of both techniques*** can be found inter alia in modern camera mobile phones that allow a store-and-forward transmission of still images and real-time video calls alike.

1.4.3 Store-and-forward versus real-time techniques

The flexibility in scheduling makes SAF systems convenient for both parties, the individual requesting a consultation as well the individual receiving the information.

Furthermore, the startup and operational costs of SAF systems tend to be lower than real-time teleconsultations and demand less capacity for transmission.
SAF technologies are eligible for data transmission through the internet.
Interactive systems, in contrast, require the use of dedicated digital communication lines in order to rapidly transmit huge amounts of data.
(For comparison: An uncompressed, full motion, two-way video requires nearly 1300 times more bandwidth than a conventional telephone call [25].)

However, SAF systems lack the immediacy of patient contact, whereas real-time techniques allow a live interaction between the consultant, the patient and the person conducting the video imaging, usually either a general practitioner or a nurse [26].

The key question when choosing a consultation technique for a particular field in telemedicine is whether still images will suffice or whether real-time video conferencing is required. Requirements of a particular field have to be considered as well as technical aspects and patient needs.
Common types of SAF services include radiology, pathology, dermatology and wound care, disciplines in which many of the images created are already in a digital form and because images are usually interpreted on their own, without needing to see the patient in the first place.

On the other hand, in situations that require interactive examinations and real-time consultation, such as psychiatric interviews, handling emergencies or complex applications like remotely assisted surgery, one- or two-way full motion video links are necessary.

1.5 Mobile telemedicine

Mobile telemedicine is characterized by the use of mobile equipment that can easily be taken along and therefore be utilized anywhere in the world regardless of local conditions. Stationary devices are therefore replaced by small portable handheld devices, such as mobile phones and PDAs (personal digital assistants).
This practice is applied when handling emergency cases in ambulances or ships by using the mobile telemedicine unit at the emergency site and the expert's medical consulting at the base unit. Similar systems can be implemented in remote health centers, war zones or other areas of conflict.
Furthermore, mobile telemedicine home follow-ups are important issues of telemonitoring, especially for patients suffering from chronic/permanent diseases such as heart disease or diabetes.

One relatively simple but effective example of home monitoring is a telemedicine project for the self-management of type 1 diabetes that was implemented by the University of Oxford in 2005 [27].
Patients were equipped with a standard mobile phone which was connected to a blood glucose meter (see fig. 1.3).
The mobile phone software is not only designed to collect data from the meter, it also gathers relevant information from the patient:
Briefings on diet, exercise levels and the insulin dose injected are collected and immediately transmitted to a server where data can also be viewed by health care professionals. Patients get feedback by nurses via telephone and an extra histogram display of recent blood glucose levels shown on the phone screen [27,28].

Fig.1.3

http://www.eng.ox.ac.uk/samp/diabetes.html

As mentioned before, advances in technology walk hand in hand with progress in the evolution of (mobile) telemedicine.
In 1982, the European Conference of Postal and Telecommunications Administrations (CEPT) created the Groupe Spécial Mobile (original abbreviation **GSM** now stands for **“Global System for Mobile communications”**) to develop a standard for a mobile telephone system that could be used across Europe.
[29]. Due to the low bit rate and therefore limited possibility to transfer pictures in adequate quality, the application of GSM alone in telemedicine is highly restricted.

Newer technologies such as **GPRS** (General Packet Radio Service) and **UMTS** (Universal Mobile Telecommunication System), set milestones in the development of data transmission techniques.
GPRS is a mobile data service available to users of GSM and has a much higher transmission rate. UMTS is one of the third-generation (3G) cell phone technologies with high data transmission capacities.
Furthermore, satellite communication can be used for informational exchange over long distances. For short distances of up to 20 meters Bluetooth technology can be used for the exchange of data; clinical pictures can be uploaded onto computers via infrared, USB and Bluetooth [30].

Briefly summarized, new communication technologies entered the picture, allowing medical images to be disseminated electronically for educational and clinical purposes.

Data transmission has become fast and reliable, and data storage cheap. The "digital revolution" of the last decade has made it possible to transmit texts, images, recordings and video clips to colleagues around the world, and, more dramatically, has made appliances such as long-distance radiology and even telesurgery possible [31, 32].

1.6 Fields of application

The following descriptions are meant to illustrate possible applications of telemedicine in the selected areas of radiology, pathology and surgery.
The various aspects of teledermatology will be discussed thoroughly in a consecutive chapter.

Teleradiology

Seen as radiology is one of the disciplines in healthcare that do not necessarily require interactive contact with the patient, this field has always been at the forefront of the emerging trend of telediagnostics.
Remote or smaller hospitals, where the volume of radiology may not justify having a radiologist on-site (or at least not permanently), may not need to maintain specialist staff which can be seen as a big economical advantage and saves patients from travelling to a larger center.

Increasingly powerful picture archiving networks such as PACS (Picture Archiving and Communications System) permit the digital transmittance of diagnostic images such as MRIs, CT scans or radiographs to major centers that might otherwise be inaccessible to certain patients.
PACS are networks dedicated to the storage, retrieval, distribution and presentation of images. The most common format of data storage in PACS is called DICOM (Digital Imaging and Communications in Medicine).
Most PACSs handle images from various medical imaging instruments, including ultrasound, magnetic resonance, PET, computed tomography, endoscopy, mammograms, etc.
A full PACS system should support multiple modalities and interface with existing hospital systems such as RIS (Radiology Information System).
Despite the electronic files (i.e. in CT scans) being very large, studies indicate that the process of image compression, transmission, decompression and display on relatively low resolution monitors does not reduce the ability of radiologists to interpret the images [33].

Teleradiology is widely used in the USA, where it has been shown to be safe and, under the right circumstances, economical [34].
The economics depend on the workload, the distances involved, and what equipment needs to be purchased [35].
It is becoming more common in Europe, especially for emergency reporting.

Telepathology

Similarly to teleradiology, telepathology is a branch of telemedicine where mainly still images are processed.
Store-and-forward systems in telepathology work analogically to other fields of telemedicine: Images are captured, stored, retrieved and transmitted to distant sites for various purposes.
Real-time systems, however, harness robotic microscopes that allow the telepathologist to choose and change his/her field of view and magnification at will.
A microscope emulator has been developed and the term "Virtual Pathology Slide" (VPS) has been coined [36].
In 1989, investigators in Norway were the first to provide operative frozen-section services to several rural hospitals via telepathology [37].
Telepathology makes it possible for small hospitals without a pathologist on-site to provide operations requiring an operative histopathologic diagnosis. Telepathology also can be used to support an isolated pathologist for second or expert consultation or even to transfer the complete diagnostic work to another facility, as described by Dunn et al [38].

Telesurgery

In telesurgery, the goal is to develop robotic tools to augment or replace hand instruments used in surgery. The robotic tools as such are not automated robots but teleoperated systems under direct control of the surgeon.
Contrary to other telemedical fields, telesurgery goes beyond serving the purpose of diagnosis. In fact, telesurgery is a manipulative domain on a highly sophisticated technical level and the dawn of a new era.

Telementoring, which is part of robotic telesurgery, involves a remote surgeon supervising the surgeon on-site with the possibility to actively participate in the operation and to perform particular manoeuvres him/herself. In actual telesurgery, the surgeon performs the operation from a remote location without any further manipulation on-site. In both cases, the consoles of both surgeons are connected and run the same surgical robot [39].

Medical robotics are an active area of research, not only in the planning and execution of surgical operations but also in surgical training.
Again, military-medical considerations led to the development of medical robot systems. The idea was to perform emergency surgeries on soldiers in combat zones without hazarding surgeons on-site. However, the long setup and operation times rendered this system unsuitable in frontline surgery, except for several isolated cases [40].

Another idea was to apply this system to the surgical care of astronauts.
Minimally invasive surgery began in 1987 with the first laparoscopic cholecystectomy. Since then, the number of procedures performed laparoscopically has increased immensely [41].
Along with improvements in technology this development paved the way for telesurgery. RoboDoc was the first robotic surgical system and was used to core the femoral shaft for total hip replacement [42].
The second generation of surgical robots was developed around 1989 at the Research Center in Karlsruhe but was never used in clinical practice [43].

The Zeus™ robot system (Computer Motion, Galeta, CA) was the first surgical robot developed for commercial purposes. It has three arms, one of which is voice controlled and operates the camera, the other two are for instruments that are connected to the console via a joystick-like control element.

Zeus Robot Arms

Fig. 1.4

http://trueforce.com/Medical_Robotics/Medical_Robotics_Companies/zeus.htm

Zeus Console

Fig.1.5

http://trueforce.com/Medical_Robotics/Medical_Robotics_Companies/zeus.htm

The surgeon views the camera picture on a monitor on the console and can see and move the instruments in real time. The ratio of the surgeon's hand movements to those of the instruments can be adjusted individually. This way tremor can be avoided and the precision of the surgeon's movements can be increased.
In 2001, Prof. Marescaux used the ZEUS robot and successfully performed a cholecystectomy in Strasbourg, France from New York, which was the first transatlantic operation of this sort [44].
The first robotic operation in Austria was performed in the department of H.-J. Mischinger on March 16, 2001 [45].
Together with S. Uranues et al, eight abdominal and seven heart operations were performed with the ZEUS robotic system between March and July 2001 [39].

Telesurgery is probably the most sophisticated field in telemedicine up until now and demands a lot of expertise and skill from both surgeons and technicians.
Telesurgery, still in its infancy, is mainly used to train surgeons in endoscopic techniques and for consultations and telementoring. In the long term, though, experts expect it to be used on the battlefield, in space, in remote regions or in hospitals that lack a specialist to perform a complex operation. [46]
Whereas telesurgery has shown to be safe and technical obstacles have been overcome to a large extent, the costs of remote operations may be a reasonable concern. Telesurgery has become feasible, yet it still has to become economically viable.

1.7 Tele-education

Telemedical applications do not only aid diagnosis - educational benefits for doctors, students, as well as medical staff in general can also be drawn.

Exchange of knowledge
Terms known as *"tele-teaching"* or *"e-learning"*, offer new perspectives for student education and professional training, not only in medical domains.
The Medical University of Graz (MUG) for example offers an internet-based university-wide learning tool called "Virtual Medical Campus" (VMC- http://vmc.meduni-graz.at).

VMC facilitates knowledge acquisition through practically orientated (videos, tutorial trainings with elaborate feedback etc.) computer-based training and supports face-to-face teaching.

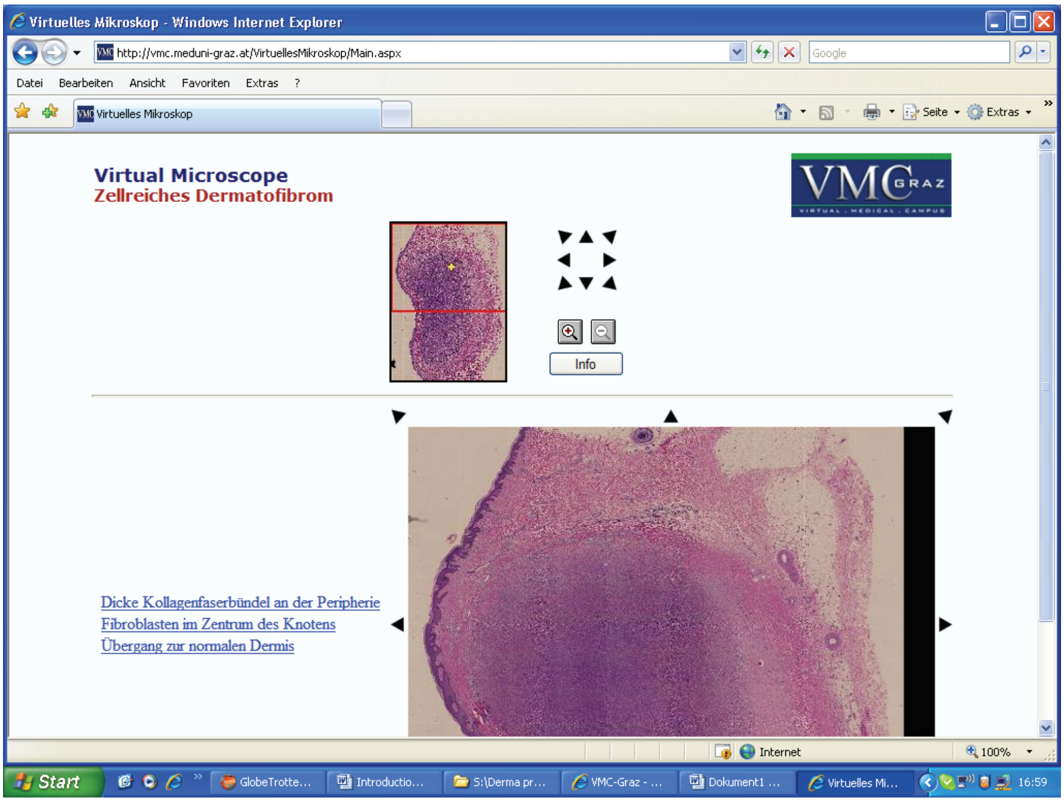


Fig.1.6

vmc.meduni-graz.at

The university clinic also offers an International Dermoscopy Diploma, an interactive online course that goes way beyond merely providing an Internet textbook (http://www.medunigraz. at/dermoscopy/).

Exchange of experiences

Telemedicine facilitates the exchange of expert opinions on an international level. People operating in medical professions have the opportunity to use online forums in order to discuss diagnostic or therapeutic questions without the patient being directly involved. This sharing of experiences may contribute to quality management in Medicine.

There is a tendency towards a "person-centered health system", an approach to empower patients to adopt an active role in managing their own health status and, in addition, facilitating the early diagnoses of diseases [47].
Home monitoring can be listed as one of many examples in this context.

In this chapter a selection of different approaches to e-health as well as future prospects are discussed. Apparently, telemedicine exceeds the use in specialties and plays an important role in the professional training of medical staff as well as, in part, patient education.

In the times of Google, weblogs, net doctors and flimsy healthcare websites, patients are confronted with vast amounts of unfiltered information.
An unprecedented flood of information needs to be untangled in order to be able to provide reliable information on health-related topics in a high quality manner.
In order to increase quality and trustworthiness in online health information, the Health On the Net (HON) Foundation was created in 1995.
HON is a non-governmental organization based in Switzerland that aims to help both laypersons and medical practitioners to find useful and reliable health information online.
The principles of the HON code of conduct can be found on the HON website (www.hon.ch) as well as in leading online dictionaries such as Wikipedia. They include confidentiality, transparency of authorship and sponsorship as well as justifiability.
Another highly active independent group more recently constituted, and congregating a large number of international stakeholders, is the Internet Healthcare Coalition [48].

1.8 Telemedicine - Fear and loathing

Change does not necessarily mean progress. Some people say telemedicine is one of the most important innovations of our times, a large claim that certainly does not meet ubiquitous approval.
Some people, especially those with misgivings about technology, see telemedicine as a threat and are concerned that the traditional doctor/patient relationship may be eroded [49,50].
New security concerns arise, seen as a lot of confidential information is sent via the World Wide Web.
Breaches in confidentiality may entail distrust towards telemedicine in general.

Furthermore, contentious matters such as remuneration, reliability and accountability in case of false diagnosis have to be considered [51].
Economic, ethical and medico-legal issues require thorough consideration in both telemedicine and conventional medical applications alike.

1.9 Legal and ethical aspects

New techniques raise new ethical and other related challenges. Telemedicine is often practiced across boarders which can provoke problems due to varying jurisdiction in different countries and/or states.
The key question in this context is whether a practitioner licensed only in jurisdiction A who treats a patient in jurisdiction B violates B's laws, a problem that is commonly addressed as a "Conflict of Laws" [52].

Ethical principals include matters such as ensuring confidentiality, and contemporaneous record-keeping.
As a matter of course, teleconsultants are bound to professional discretion in equal measure to their colleagues on spot.
Furthermore, doctors using technical pathways of data transmission have to ensure data protection and, if applicable, encode personal data for transmission [51].

In traditional patient care, where patient data is stored conventionally, care must be taken to ensure that physicians as well as non-physician intermediaries, e.g. technicians, who collect data and have access to databases observe confidentiality.
In telemedicine, data privacy is additionally at risk due to means of electronic eavesdropping, e.g. hacking, and special care is needed to prevent inadvertent copying of communications such as diagnoses.
Where patients are treated or monitored in their homes, family members may become, and perhaps need to become, involved in their care, and have access to information.
Practitioners at a distance from patients should ensure, as much as they can, that local personnel have informed patients of this and have obtained their agreement.

Maintaining and protecting the integrity and physical protection of data and systems, privacy and confidentiality of individual health information are the areas of greatest concern in the implementation and use of the internet and other interactive applications in health and health care [53].
Another fear is that current developments may finally lead to what is called the “virtual naked patient”, where employers for example can easily obtain information regarding the health conditions of their staff and applicants.

The European Union first published a Directive in 2001 that contained telemedicine as part of its provision. This E-commerce directive, as it became known, created the basic legal framework for electronic commerce in the Internal Market. The Directive removes obstacles to cross-border online services in the European Union and provides legal certainty to business as well as citizens.
Nevertheless, there is no internationally accepted policy framework that addresses the basic rights and responsibilities of users and providers [51,52,53].

Guidelines, codes and ubiquitous regulations are in order to decrease violations in confidentiality.
The doctor-patient relationship is undoubtedly a different one, seen as important aspects (such as face-to-face communication and touch) are unavailable [49].
Benefits and disadvantages have to be considered thoroughly before implementing telemedical applications; patient satisfaction needs to be evaluated repeatedly.

1.10 Successful implementation of telemedical appliances

New technologies alone do not create change.
A more or less explicit controversy will always arise when a new technique is implemented ("social negotiation").
Telemedicine is often ranked among the more significant developments over the past decades, yet it has primarily been used on a small scale in clinical activity.
Reviewing literature, the results are dominated by feasibility and evaluation studies as well as experimental services, most of which do not endure beyond specific research and development projects. Only in teleradiology has there been any evidence of normalization—a move toward the routinized embedding of telemedicine in everyday clinical practice [34].

Talking about "digital revolution" and the vast possibilities in e-health and related fields two major questions arise:

What is the reason for the low routine clinical use of telemedical applications?
It is commonly suggested that the main reason for the low routine clinical use of telemedical applications is the insufficient evidence of its efficacy, in terms of both clinical and organizational impact on the health care sector.
Fundamental points in telemedicine are: clinical effectiveness, cost effectiveness and patient satisfaction.
Systematic reviews of either key problem [35, 36, 37] refer to a lack of evidence or rather to the poor quality of existing evidence.
Evaluation and high quality evidence are understood to be a vital link between implementation and successful integration of telemedicine systems in practice.
According to May et al [34] proponents of tele-health care systematically underestimate its complexity, with this underestimation then leading to failure of several services.

What criteria should be satisfied when trying to implement a telemedical strategy successfully?
Out of 12,000 articles initially retrieved in 2006, Obstfelder et al [54] only identified 16 studies of telemedical applications in clinical use.

Analyzing those, they tried to find several characteristics they all have in common in order to establish possible criteria for the success of telemedical applications (figure 1.7).

CRITERIA FOR SUCCESS
1)**Local health care service delivery problem is clearly stated** An effort is made to describe the local health-related challenges that the technology is intended to solve
2) **Telemedicine is recognized as a benefit** A telemedical application is seen as a potential solution to the challenge (cf. Criterion 1)
3) **Telemedicine is seen as a solution to medical and/or political issues** Equal access to health care is often a major concern, justifying the implementation of telemedicine
4) **There is collaboration between promoters and users** Successful implementation depends on teamwork, involving the initiators of the technology as well as the managers, clinicians, and Patients
5) **Issues regarding organizational and technical arrangements are addressed** Successful implementations are often characterized by a sound anchoring in established organizations and technical structures, or by the establishment of new structures
6) **The future operation of the service is considered** Plans for future use and for future financing are important to success

Fig.1.7 [54]

It is important to admit that telemedicine may be of use in many specialties, but not in all. The types of problems for which telemedicine is seen as a solution vary greatly.
One requirement for success (see also Criterion 2) is to evaluate whether telemedicine can be the right tool for clinicians when dealing with a particular task.
These questions should be discussed individually and on an interdisciplinary level.

2. Teledermatology

Teledermatology is one of telemedicine's many subcategories.
As a visual profession with low mortality and many chronic conditions, Dermatology can be seen as a promising candidate for various aspects of telemedicine in general as well as mobile telemedicine in particular. Besides clinical applications, branches of teledermatology include teledermathopathology and teledermoscopy [55,56].
Mainly store-and-forward techniques (see chapter 1.4.1) are in use, where sets of digital images of skin diseases accompanied by a short patient's history are referred to a dermatologist for further evaluation.

The term "teledermatology" was coined by Perednia and Brown in 1995 [1].
They implemented a teledermatology application (*Oregon High-Performance Computing and Communications teledermatology project)* in a rural area in the United States which was undersupplied with dermatologists. The Eastern part of Oregon was accommodated by only two dermatologists in charge.
However, no detailed results concerning diagnostic validity were presented.

Two years later, in 1997, the first study on diagnostic congruence between face-to-face diagnoses and remote diagnoses in teledermatology was conducted in a nursing home in Minneapolis, Minnesota (USA) [57].
29 residents with a total of 30 skin conditions were enrolled. A nurse collected and sent the pictures in combination with the patients' histories to 3 dermatologists who each determined a diagnosis independently.
The results were then compared with the diagnoses made by a dermatologist on-site two days after the pictures had been collected. Agreement was reached in up to 88 percent.
Many studies on the diagnostic reliability, cost effectiveness and other aspects of teledermatology have been performed since.

A number of comparing studies have demonstrated that teledermatology generally represents a useful diagnostic tool, especially in communities undersupplied with dermatologists [25,57,58].

In terms of effectiveness, reliability, accuracy, and patients' satisfaction all have been experienced with variable benefits.
The spectrum of diagnostic agreement has shown to range between 53 and 100%. [30, 57,59,60,61].
Most published studies have compared diagnostic capabilities of teledermatology to our traditional face-to-face evaluations, using face-to face diagnosis as the clinical standard (gold standard) without taking histological findings into account.

Furthermore, dermatologists have varying levels of experience and educational standards. This so-called "inter-observer variability" may also influence the level of agreement [61].

One of the major problems in teledermatology is the inability to palpate the lesion. Palpation in dermatologic diagnosis is seen as an important diagnostic tool.
Sense of smell is yet another perception that can aid diagnosis (e.g. when assessing leg ulcers) and is missing in teleconsultations.
Moreover, the teledermatologist only views selected details of an image and not the whole surface of the skin, as ideally occurs in face-to face examinations.
Thus, important secondary diagnoses may be missed [1].

An increasing proportion of patients with skin diseases are being diagnosed and managed without ever seeing a dermatologist. Primary care physicians are attempting to bridge the widening gaps in the care network, despite the fact that many have no formal training in dermatology. Thus, teledermatology might be implemented as a filtering or triage system allowing a more sensible approach for the management of patients with emergent skin diseases.

2.1 Mobile teledermatology

Like mobile telemedicine (see chapter 1.5), mobile teledermatology is characterized by the use of mobile equipment such as technologically advanced camera phones or PDAs.
The first study on the subject was published in 2005. Braun et al [30] evaluated the feasibility of telemedical wound care consultation in the management of chronic leg ulcers. Two remote physicians and one on-site had to evaluate 61 leg ulcers for variables such as epithelialization, fibrin, necrosis, and granulation tissue.
The pictures were obtained with a mobile phone and immediately sent via email.
Even though the study was performed using first generation mobile devices the agreement between remote and face-to-face evaluations was very good, with κ- values of up to 0.94[iii].

In the same year Ebner et al [62] investigated the diagnostic agreement between teledermatology based on images from a mobile phone camera and face-to-face (FTF) dermatology including a wide range of skin diseases. 58 subjects with visible skin lesions of any kind were included in the study. In 75% o all cases telediagnosis using a mobile phone was fully concordant with direct, physical examination by a dermatologist.

In 2007, the first study performing mobile teledermoscopy using cellular phones with an in-built camera was conducted. Within the framework of a pilot study, colleagues from the Department of Dermatology, Medical University of Graz, Graz (Austria), investigated the feasibility of performing melanoma screening with both clinical and dermoscopic images acquired using a new generation of cellular phones [63].

The study conducted within the scope of this thesis focussed on a wide range of tumorous skin lesions, benign as well as malignant, and investigated the feasibility of performing skin tumor screening using modern camera phones for taking both clinical and dermoscopic images.

[iii] Cohen's κ (kappa): Kappa is always less than or equal to 1. A value of 1 implies perfect agreement and values less than 1 imply less than perfect agreement.

3. Clinical study

The increasing incidences of cutaneous tumors in general, as well as the high mortality of melanoma in particular, present a great challenge to the development of screening tools for skin tumors.
Mobile teledermatology has the potential to become a well applicable filtering or triage system, allowing a more sensible approach for the management of patients with emergent skin diseases. Furthermore, it may become a screening tool for malignant cutaneous tumors.

Dermoscopy (in the past also called epiluminescence microscopy, dermatoscopy, surface microscopy) is a non-invasive, in vivo technique that is increasingly used in dermatology for the management of patients with pigmented skin lesions.
It represents an additional tool to improve diagnostic accuracy compared to diagnoses solely based on naked-eye examination [64].

Teledermoscopy represents a recent development of teledermatology. Dermoscopic images alone or in combination with clinical images could not only aid the diagnosis of skin lesions for clinicians as a second-level procedure for the evaluation of selected lesions. Dermoscopy in the framework of mobile teledermatology could also improve the accuracy of primary care physicians to triage lesions suggestive of skin cancer without increasing the number of unnecessary expert consultations.

In our study we investigated the feasibility of performing remote skin tumor screening using two mobile devices. A modern camera mobile phone was used in combination with a pocket dermoscope in order to acquire both clinical and dermoscopic images of a wide range of tumorous skin lesions that were then transmitted to a teleconsultant for further evaluation.

3.1 Material and methods

Over a period of 2 months 100 patients with a total number of 119 tumorous skin lesions (both benign and malignant) were selected coincidentally from the general outpatient clinic at the Department of Dermatology, Medical University of Graz, Graz, Austria.
In each case a close-up clinical image and a dermoscopic image applying the cellular phone on a pocket dermoscopy device was obtained.
Patients seeking medical advice by virtue of one or more skin tumors without prior treatment or consultation in that matter were included in the study after written consent had been obtained.
The study was conducted with a modern cellular phone (Nokia N73) with a built-in 3.2 megapixel camera with autofocus, macro mode and zoom. For a second series of images a pocket dermoscopy device (DermLite II PRO HR) was used to obtain dermoscopic pictures of all lesions.

In each case both close-up clinical images and dermoscopic images applying the cellular phone on a pocket dermoscopy device have been taken.
Up to three pictures per lesion were taken with each device and transferred to a computer using an USB port where they were saved along with individual-related data concerning the patient (age, sex, localization of the skin lesion/s).

The stored data was then sent to an experienced teleconsultant via a virtual private network (www. dermahandy.net/default.asp, e-derm-consult GmbH - Graz, Austria) using a store-and-forward system.
Clinical images were uploaded time-lagged from the dermoscopic images and therefore evaluated separately by the teleconsultant.
For privacy reasons pictures have been made unrecognizable, i.e. no whole faces have been shown.

The teleconsultant reviewed and evaluated clinical and dermoscopic images irrespectively and sent his response directly through the same web application. A diagnosis was made solely based on this information. One differential diagnosis was allowed.

The main aspect of the study was to evaluate the concordance between the telediagnosis made through the web application and the face-to-face diagnosis made by the on-site dermatologist in the outpatient clinic using the FTF diagnosis as a "gold standard".
The medical care of the patients was not influenced by the outcome of the teleconsultations.

In cases where an excision was made for histological evaluation, the telediagnosis was additionally compared to the histological findings.
In these cases, the face-to-face diagnoses were also compared to the histological results in order to evaluate the accuracy of FTF diagnoses.

3.1.1 Pictures

All images (clinical as well as dermoscopic) have been acquired under routine conditions and without additional light sources using a Nokia N73 mobile phone with a built-in 3.2 megapixel camera with Carl Zeiss optics, autofocus, macro mode and zoom.

The clinical images were taken using the *autofocus mode* and without using any additional devices.
In order to obtain dermoscopic images, a standard pocket dermoscopy advice (DermLite II PRO HR) was used.
The DermLite was applied directly onto the lesion and underneath the camera lens with the camera settings being on *macro mode* without using flash in order to avoid reflections that would have a negative effect on picture quality.

3.1.2 Mobile phone

Fig.1.8

http://files.airgamer.com/handys/n73/02_ss_nokia_n73_350x414_02.jpg

Product name: Nokia N73

Dimensions: Weight: 116 g

Height: 110 mm

Width: 49 mm

Thickness (max): 19 mm

Camera specifications: 3.2 megapixel camera (2048 x 1536 pixels) with up to 20x digital zoom

Picture format: JPEG

Wireless connections: Infrared

Bluetooth

3.1.3 Dermoscope

Fig. 1.9
www.dermlite.com

Product name: DermLite II Pro-HR „High Resolution"(3Gen, LLC - Dana Point, USA)

Product information:
- Large 25mm 10x lens
- 32 light-emitting diodes (LED)
- Rechargeable lithium-ion battery
- Attachable to cameras
- Pocket size
- Weight: 99g

One to three pictures of each lesion were taken with either device.
In a few cases, the picture quality of either the clinical or the dermoscopic was not sufficient, so that only one picture type could be uploaded for teleconsultation.

3.1.4 Data transmission

Images were transmitted in combination with anonymous clinical basis data (age, sex, localization, time of onset etc.) by dint of a web application based on a store-and-forward system.
The web application was provided by *e-derm consult gmbh*, Graz, Austria and was specially designed for the purpose of this study.

Images were transferred to a computer using an USB port and had 627x470 pixels resolution with macro mode. They were stored in JPEG format with an average size of 250 kilobytes.

3.1.5 Website

The dermahandy.net web application is a recent development of the *telederm.org* project, which was conceived in 2002 by H. Peter Soyer and colleagues with the contribution of the Department of Dermatology of the Medical University of Graz. This service is aimed at exchanging knowledge and expertise on a worldwide level with the goal of creating a ***DermOnline Community*** [65].
The website is available in English, German, Italian and Turkish.
Only doctors and other people working in medical domains can register and need to be approved by a network administrator.
One can either register as “client” submitting requests or “expert” reviewing them or both.
After entering the correct username and password teleconsultations can be requested through a secure internet connection.
Up to three images in JPEG format can be uploaded per request. Clinical data can be filled in a specially designed form below the picture bar.

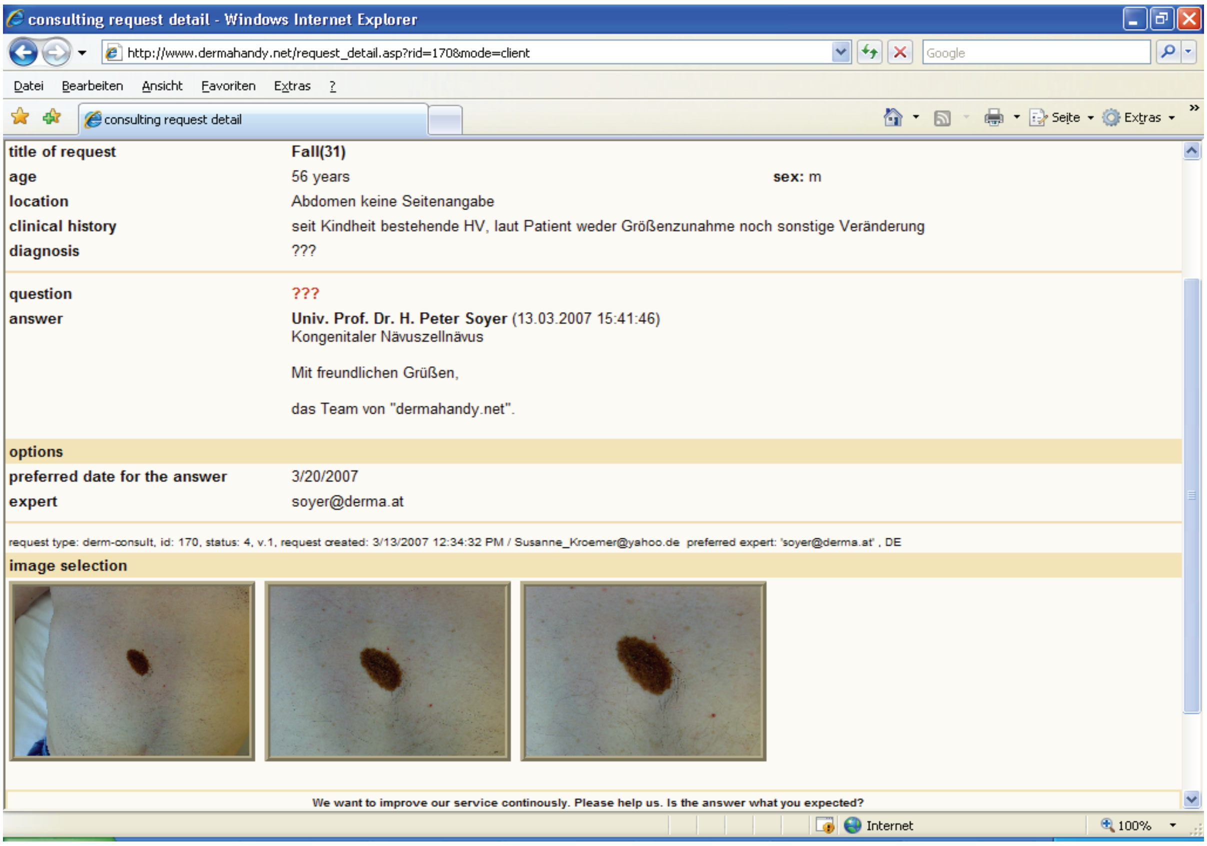


Fig.1.10

www.dermahandy.net/default.asp

The request can be sent to an expert of choice as long as his/her status has been acknowledged by the operators of the web application.

Requests can be sent to selected teleconsultants only or uploaded in a forum that is open for discussion to all members of the web portal.

No data is passed on to any third party.

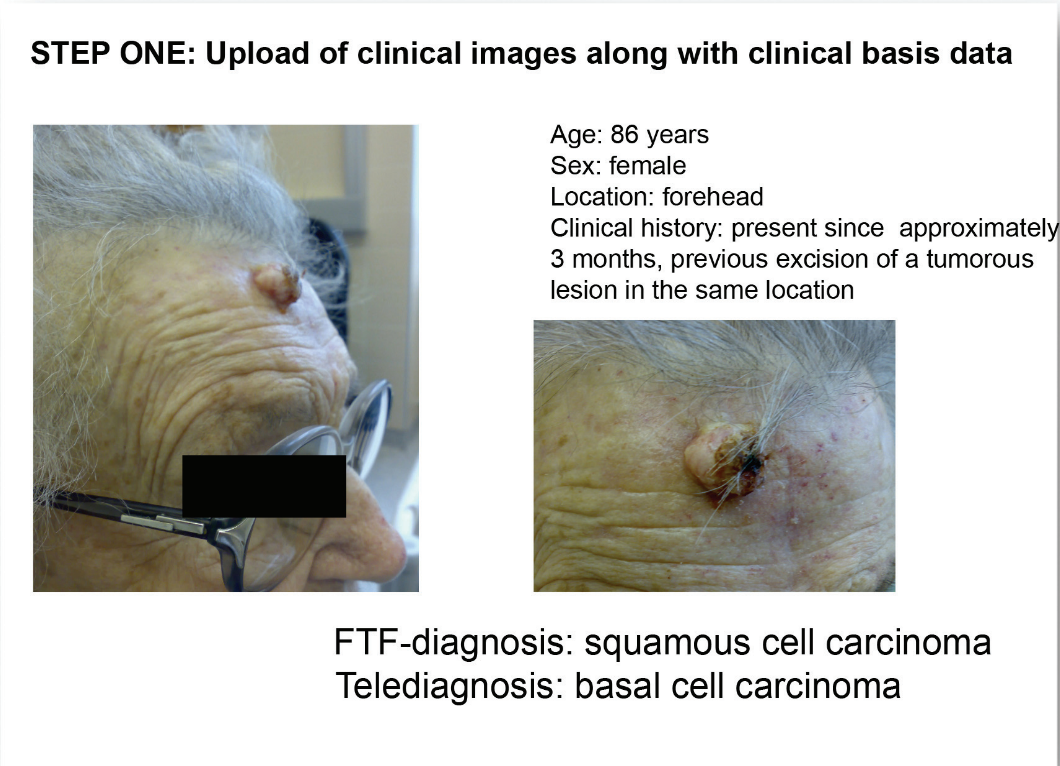
Within the scope of this thesis requests were sent to one particular teleconsultant, Prof. Dr. Hans-Peter Soyer, a professor at the Department of Dermatology in Graz, Austria who is well experienced in the area of teledermatology and dermoscopy.

3.1.6 Tele-evaluation procedures

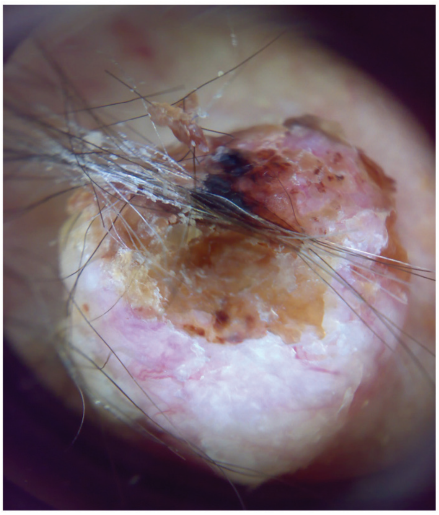
The prior objective of the study was to evaluate the concordance between telediagnosis (clinical and dermoscopic) and face-to-face diagnosis, using FTF diagnosis as a gold standard.

As a first step only the clinical pictures taken with the mobile phone camera were uploaded. After completing the clinical request, the dermoscopic images were uploaded in a second step with a time delay to ensure separate evaluation.
In cases where telediagnosis of the clinical and/or the dermoscopic image did not comply with the FTF diagnosis a third step was taken, in which clinical and dermoscopic images of the particular case were uploaded together to evaluate a possible diagnostic benefit.

In cases where a histology has been obtained, all diagnoses (FTF and telediagnoses) have also been compared to the histological findings.



STEP TWO: Upload of dermoscopic images along with clinical basis data

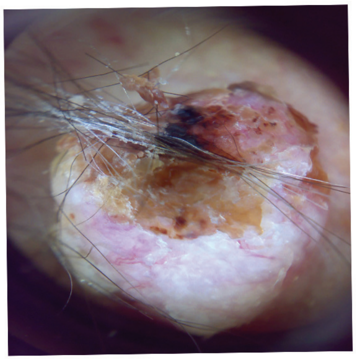


Age: 86 years
Sex: female
Location: forehead
Clinical history: present since approximately 3 months, previous excision of a tumorous lesion in the same location

FTF-diagnosis: squamous cell carcinoma
Telediagnosis: basal cell carcinoma

STEP THREE (optional): Upload of clinical images along with dermoscopic images and clinical basis data

Age: 86 years
Sex: female
Location: forehead
Clinical history: present since approximately 3 months, previous excision of a tumorous lesion in the same location



FTF-diagnosis: squamous cell carcinoma
Telediagnosis: squamous cell carcinoma

4. Results

Statistical analysis

Statistical analysis was performed using SPSS 14.0 (SPSS software package, SPSS Inc.,Sunnyvale, CA).To compare telediagnoses to FTF-diagnoses proportions were calculated. Furthermore, diagnostic concordance between telediagnoses and histopathologic diagnoses were calculated using Cohen's kappa (k) statistics. A value of 1 indicates perfect agreement. A value of 0 indicates that agreement is no better than chance.

Individuals' demographics

A total of 100 patients between 4 and 94 years of age (m:f = 43:57) were asked to take part in the study, 3 others refused participation.

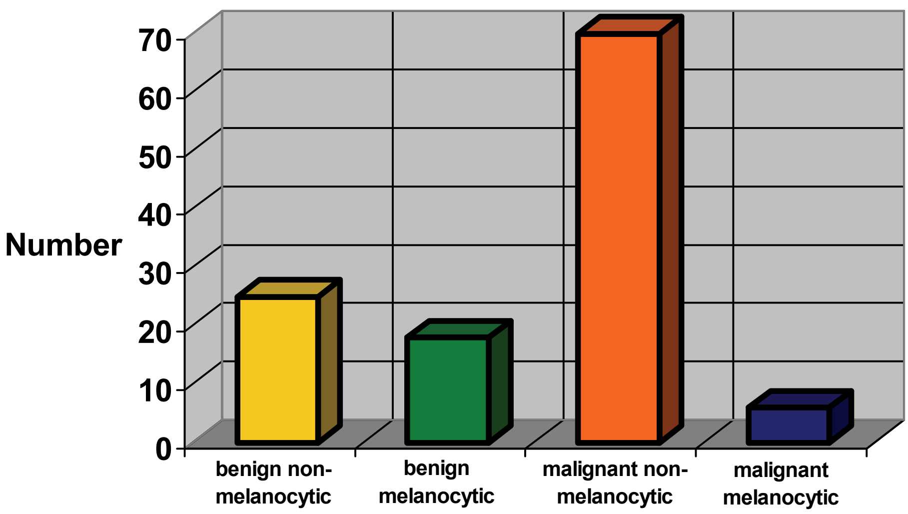
The intended purpose of the study was explained thoroughly to all patients.

Only those who agreed to participate and signed the patient consent form were enrolled.

Lesions and categories included in study

A total of 119 tumorous skin lesions were included in the study, benign and malignant as well as melanocytic and non-melanocytic.

Each lesion was assigned to one out of the following categories: benign melanocytic (18 lesions), benign non-melanocytic (25 lesions), malignant melanocytic (6 lesions), malignant non-melanocytic (70 lesions).



Benign melanocytic

Diagnosis	Total No.
congenital nevi	7
blue nevi	2
black nevi	1
dysplastic nevi	4
lentigo simplex	2

Malignant melanocytic

Diagnosis	Total No.
melanoma in situ/lentigo maligna	5
epidermotropic metastasis of malignant melanoma (MM)	1

Benign non-melanocytic

Diagnosis	Total No.
fibroma	2
fibropapilloma	2
seborrheic verruca	7
angioma	3
hypertrophic scar	1
subungual hematoma	1
mollusca contagiosa	1
dermatofibroma	1
chondrodermatitis nodularis helicis	1
inflammatory epidermal cyst	1
sebaceous nevus	3
nevus flammeus/teleangiectaticus	1

Malignant non-melanocytic

Diagnosis	Total No.
basal cell carcinoma (BCC)	36
Bowen's disease	5
squamous cell carcinoma (SCC)/spinalioma	13
actinic keratosis (AK)	16

67.2% (80/119) of all lesions have been excised for histological clarification.
In these cases clinical diagnoses as well as telediagnoses were compared to the histological findings in a later statement.
The diagnostic concordance between FTF diagnoses and histology was 85% (68/80), the accord with telediagnoses will be listed separately.

4.1 First step: Tele-evaluation of *clinical* images

A total of 330 clinical images of 117 lesions were uploaded and diagnosed via web application, pictures of 2 cases had to be singled out due to poor picture quality.

4.1.1 Agreement between telediagnosis of clinical images and FTF diagnosis

There was an overall diagnostic concordance of 86.3% (101/117) between face-to-face diagnoses and the telediagnoses.
Split up into the four categories the concordance ranged between 100% and
82.9%:

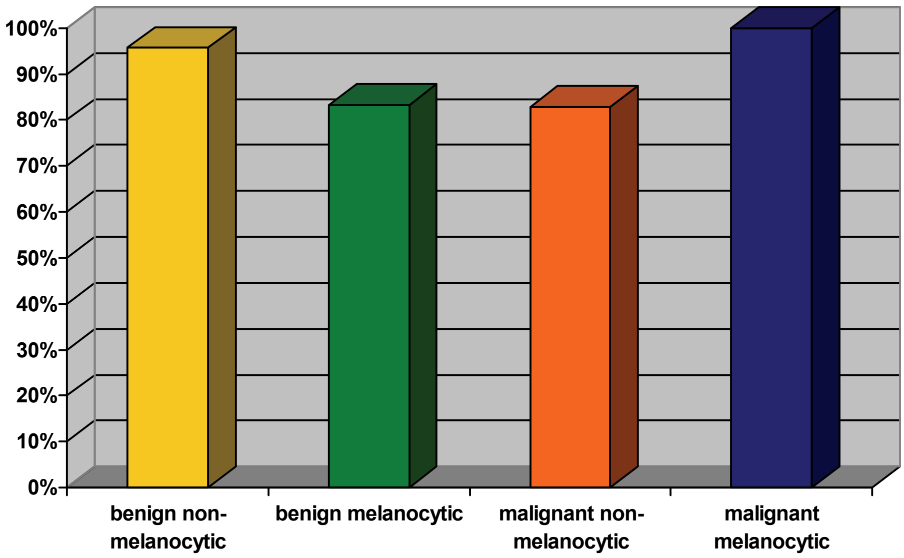
Malignant melanocytic lesions
Telediagnosis was consistent with the clinical diagnosis in 6 out of 6 cases, resulting in a diagnostic concordance of 100% with impaired significance due to the very low number of cases.

Benign non- melanocytic lesions
The agreement between FTF diagnosis and telediagnosis was 95.7% (22/23)

Benign melanocytic lesions
In 83.3% (15/18) the telediagnosis was in conformity with the FTF diagnosis.

Malignant non-melanocytic lesions
Diagnostic concordance was reached in 82.9% (58/70).

Concordance between telediagnosis of clinical images and FTF diagnosis



4.1.2 Agreement between telediagnosis of clinical images and histology

In 82.5% (66/80) of all cases the telediagnoses of clinical images were in agreement with the histological diagnoses.

In 8 cases, both the FTF and telediagnosis did not correlate with the histopathologic diagnosis, the other 6 were detected by FTF evaluation, not by tele-evaluation.

In 1 case the telediagnosis outmatched the FTF diagnosis:

In order to measure the agreement between telediagnosis and histopathologic diagnosis Cohen's Kappa was calculated. The correlation coefficient showed moderate agreement with the value of κ being 0.54.

4.2 Second step: Tele-evaluation of *dermoscopic* images

Dermoscopic images of 107 out of 119 lesions could be obtained successfully, the other 10 had to be sorted due to limited picture quality.

4.2.1 Agreement between telediagnosis of dermoscopic images and FTF-diagnosis

There was an overall diagnostic concordance of 76.6% (82/107) between the face-to-face diagnosis and the telediagnosis.
Split up into the 4 categories the concordance ranges between 68.4% and 100%:

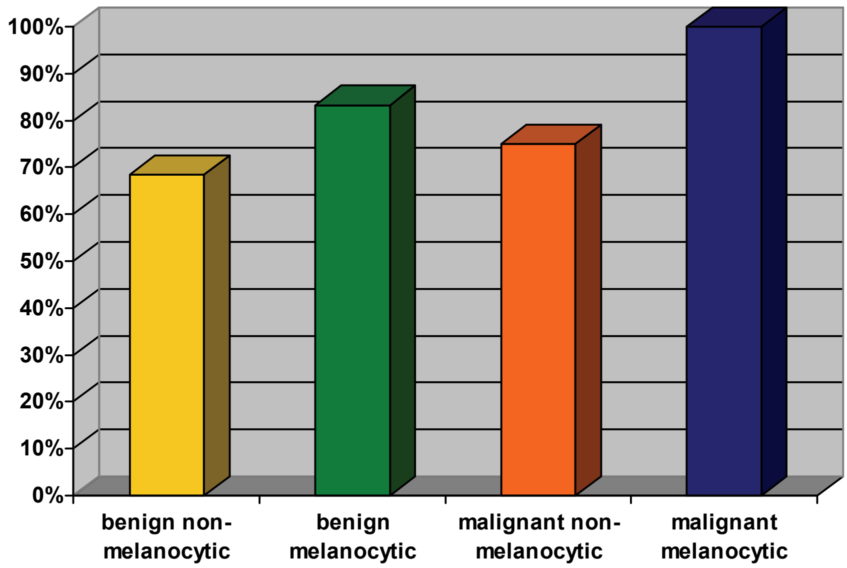
Malignant melanocytic lesions
Analogous to the concordance of clinical images in this category, the telediagnosis of dermoscopic images was consistent with the clinical diagnosis in 6 out of 6 cases, resulting in a diagnostic concordance of 100% with impaired significance due to the very low number of cases.

Benign melanocytic lesions
In 83.3% (15/18) the telediagnosis was in conformity with the FTF diagnosis.

Malignant non-melanocytic lesions
Diagnostic concordance was reached in 75% (48/64).

Benign non-melanocytic lesions
The poorest diagnostic concordance for dermoscopic images in this category was found with a 68.4% (13/19) agreement between FTF diagnosis and telediagnosis.

Concordance between telediagnosis of dermoscopic images and FTF diagnosis



4.2.2 Agreement between telediagnosis of dermoscopic images and histology

Diagnostic concordance was reached in 74.3% (52/70).

In 8 cases, both the FTF and telediagnosis did not correlate with the histopathologic diagnosis and the other 10 were identified by the clinician on site, not by the teleconsultant.

In 3 cases telediagnosis outmatched FTF diagnosis.

Cohen's Kappa was used in order to measure the agreement between telediagnosis and histopathologic diagnosis. The correlation coefficient showed low to moderate agreement with the value of κ being 0.41.

4.3 Third step: Tele-evaluation of clinical images in combination with dermoscopic images

In cases where the telediagnoses differed from the FTF diagnoses in either one or both image types, clinical and dermoscopic images of a particular case have been uploaded *together* for re-evaluation. This was in order to evaluate whether a combination of both image types can improve the accuracy of diagnosis, an approach similar to FTF diagnosis where the doctor on-site can get a macroscopic view from a lesion and can also use a dermoscope if required.

24 lesions have been re-evaluated in that manner.

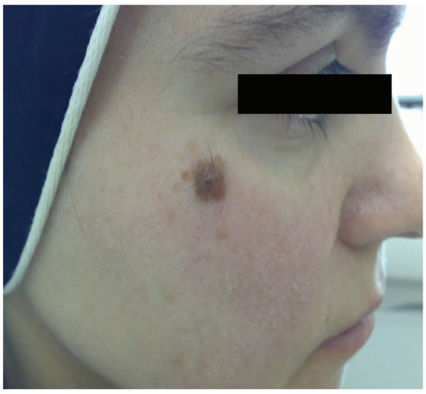
In 37.5 % (9/24) this re-evaluation finally led to the right diagnosis.

Re-evaluation of previously misdiagnosed cases

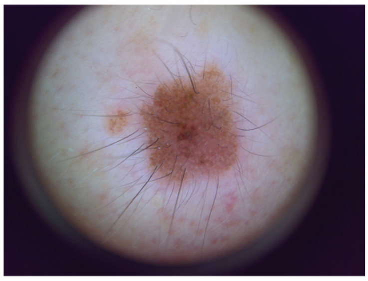
Nr.	FTF diagnosis	Telediagnosis clinical image	Telediagnosis dermoscopic image	Re-evaluation combined
11	squamous cell carcinoma	squamous cell carcinoma	basal cell carcinoma	squamous cell carcinoma
24	basal cell carcinoma	basal cell carcinoma	actinic keratosis	basal cell carcinoma
34A	basal cell carcinoma	actinic keratosis DD lentigo maligna	solar lentigo DD actinic keratosis	solar lentigo DD actinic keratosis
34B	Bowen's disease	verruca seb. DD basal cell carcinoma	verruca seb. DD actinic keratosis	verruca seb. DD basal cell carcinoma
35	nevus	melanoma	nevus	melanoma on nevus
36B	fibropapilloma	fibropapilloma	Pinkus tumor	nevus DD Pinkus tumor
39	basal cell carcinoma	basal cell carcinoma	actinic keratosis	basal cell carcinoma
40	solar lentigo	melanoma	melanoma	melanoma
42	spinalioma	spinalioma	basal cell carcinoma	basal cell carcinoma
51B	squamous cell carcinoma	basal cell carcinoma	basal cell carcinoma	basal cell carcinoma DD actinic keratosis
53A	spinalioma	spinalioma	actinic keratosis	basal cell carcinoma
54	squamous cell carcinoma [in question]	squamous cell carcinoma	actinic keratosis	amelanotic melanoma DD Bowen's carcinoma
55	basal cell carcinoma	actinic keratosis	actinic keratosis	basal cell carcinoma
58B	Bowen's disease	actinic keratosis	actinic keratosis	actinic keratosis
60	fibroma	tricholemmoma	tricholemmoma	verruca vulgaris
67	nevus non dysplastic	nevus non dysplastic	dysplastic nevus	nevus non dysplastic
70	dermal nevus cell nevus	nevus coeruleus	nevus	nevus
70A	nevus	nevus	melanoma in situ	nevus
72	nodular chondrodermatitis	nodular chondrodermatitis	gout tophi	nodular chondrodermatitis
80	basal cell carcinoma	seborrheic verruca DD basal cell carcinoma	actinic keratosis DD seborrheic verruca	seborrheic verruca
83	actinic keratosis	basal cell carcinoma	actinic keratosis	actinic keratosis
86D	basal cell carcinoma	actinic keratosis	actinic keratosis	actinic keratosis DD squamous cell carcinoma
95B	actinic keratosis	seborrheic verruca	actinic keratosis	seborrheic verruca
100	inflammatory epidermal cyst	inflammatory epidermal cyst	excoriated prurigo nodularis	excoriated prurigo DD basal cell carcinoma

4.4 Case studies

CASE 1



Age: 42 years
Sex: female
Location: right cheek
Clinical history: present since birth, inflamed hair follicle



FTF-diagnosis: congenital nevus
TD clinical: congenital nevus
TD dermoscopic: congenital nevus

CASE 2

Age: 81 years
Sex: female
Location: left shoulder
Clinical history: elevated skin lesion in the area of a preexistent scar (excision of a dermal nevus 4 years ago)
increasing itching and redness

FTF-diagnosis: hypertrophic scar
TD clinical: hypertrophic scar
TD dermoscopic: hypertrophic scar

5. Discussion

To date, most of the studies using modern camera mobile phones for the evaluation of skin tumors are characterized by a low number of cases and mainly focus on clinical images, leaving dermoscopic aspects aside.

In 2007 the first study performing mobile teledermoscopy using cellular phones with built-in cameras was conducted. Within the framework of a pilot study, Massone et al [63] investigated the feasibility of performing melanoma screening with both clinical and dermoscopic images acquired using a new generation of mobile phones. 18 patients were selected in the Pigmented Skin Lesions Clinic of the Department of Dermatology, Medical University of Graz, Graz (Austria) and the diagnoses of 2 teleconsultants were compared to the FTF diagnoses made on site. Regarding the clinical images the agreement between FTF diagnosis and telediagnosis was 89% for both teleconsultants. The concordance of dermoscopic images was found to be 89% and 94%, respectively.

Another study applying teledermoscopy was conducted by Stefani et al [66] and investigated the feasibility of teledermatology for the management of individuals exhibiting multiple pigmented skin lesions with a two-step procedure. In the first step, remote consultants selected clinically equivocal lesions evaluating a tele-transmitted clinical image of patients' backs. In the second step, dermoscopic images of selected lesions were evaluated. Management recommendations of both steps were compared with face-to-face. For a total of 465 pigmented skin lesions in 18 patients, the agreement between the face-to-face and the two remote experts resulted as moderate (k value, 0.530–0.565) in the first step and substantial (k value, 0.681– 0.703) in the second step.

In the study performed within the scope of this thesis, telediagnostic findings (clinical pictures and dermoscopic pictures were diagnosed separately) were primarily compared to FTF diagnoses. In a further step, the accordance with histological diagnosis was also evaluated.
Telediagnoses of clinical images showed to have a higher concordance with FTF evaluation than telediagnoses of dermoscopic images alone.
Re-evaluation of clinical and dermoscopic images combined was found to be of poor additional diagnostic benefit.
Overall, clinical images alone seem to be most efficient for the tele-evaluation of tumorous skin lesions.

Dermoscopy in general is most useful for the early diagnosis of malignant melanoma and for differentiating melanoma from other pigmented lesions such as atypical nevi. This is also reflected in the results of our teledermoscopic evaluations, where a very high concordance was found for melanocytic lesions (100% for malignant, 83.3% for benign melanocytic lesions).
Two benign nevi were overdiagnosed as melanoma, in one case histological clarification confirmed the FTF diagnosis and no histology was obtained from the second lesion.
The dermoscopic device used in this study was a conventional pocket dermoscope and was in no way designed to be connected to any image-taking devices, which resulted in a lower image quality. Therefore, several pictures had to be singled out and the average quality of the remaining images may give another reason for the relatively poor results of the teledermoscopic diagnoses.

In contrast to the teledermoscopy of melanocytic lesions, the telediagnostic concordance between non-melanocytic lesions and FTF diagnosis was found to be relatively low, especially for *benign* non-melanocytic lesions (68.4%).

In 85% of all histologically verified lesions, FTF diagnosis was in concordance with histology.
In a few isolated cases in which the FTF diagnosis was not consistent with the histological results it was outmatched by telediagnosis.

In this study a teledermatologic consultation was simulated and the feasibility of mobile teleconsultation using 2 handheld devices (a conventional mobile phone and a pocket dermoscope) could be proven.
A store-and-forward system in the form of a specially designed web application was used in order to transmit photographs in combination with anonymous clinical basis data.
SAF techniques are used in various fields of telemedicine (see chapter 1.4.1) and their practicability in Dermatology has been proven and tested.

There are numerous articles evaluating the diagnostic concordance of teledermatology.
In most studies FTF diagnosis functions as a gold standard and the diagnostic capabilities of teledermatology are compared to our traditional FTF evaluation.
This makes sense insofar as it depicts a direct comparison of visual findings (regardless of results of further examination), which is the working hypothesis in everyday clinical practice. Furthermore, not all lesions are excised, thus, histopathologic evaluation is only carried out in a certain number of cases.

Ideally, clinical diagnosis is in conformity with the histopathological diagnosis.
Yet this is not always the case in everyday practice.
Another issue that may influence results to the disadvantage of teledermatology is the so-called “inter-observer variability”, referring to various levels of experience and training amongst dermatologists.
Inter-observer variability measures the level of agreement between different dermatologists [67].

5.1 User-friendliness

According to the graduand both devices used in this clinical trial (Nokia N73 camera phone and DermLite II PRO-HR dermoscope) are easy to handle, user-friendly and well applicable in everyday clinical practice.
Both devices had rechargeable batteries and scored with relatively low power consumption.

Even when many pictures were taken and both devices were turned on for a longer period of time they rarely had to be recharged, which can be seen as a big advantage in mobile telemedicine.
One disadvantage in the use of the camera phone was the relatively poor picture quality under bad lighting conditions, a problem that will probably take a back seat in the future due to the rapid technological evolution of cameras and camera phones.
The image quality, irrespectively, can be compared to conventional digital cameras.

Currently, telemedical research is focusing on providing tools for improved self-examination, thus contributing to the already mentioned aspects of filtering and triage systems in health care. The user-friendliness of applicable tools therefore plays an important role and needs to be ensured as well as patient satisfaction.

5.2 Data transmission

Images and case related data were saved on a computer before they were transmitted to the recipient.
This was mainly necessary in order to transmit clinical images and dermoscopic images separately and with a time delay.
Furthermore, pictures revealing the identity of patients had to be made unrecognizable.

An important aspect of mobile devices such as PDAs and mobile phones is the possibility to send data directly via MMS or email without previous transmission to a different storage location.
It is to be assumed that the type of data transmission has no influence on the quality of the pictures.
In their study on wound management of leg ulcers using the camera of a mobile phone (Nokia 7650), Braun et al [30] compared the transmission of images via email and Bluetooth. The mode of data transmission appeared to have no influence on image quality.

6. Conclusion

Summarizing, one can say that the mobile telemedical applications tested within the limits of this thesis seem to be applicable to make expert knowledge in Dermatology available over long distances.

Residual technical problems such as limited image quality under bad lighting conditions will soon be overcome thanks to the ongoing progress in modern technology.

Telemedicine in general as well as Teledermatology in particular are vastly growing domains and constant subjects of research.
Despite advances in technology, certain issues have to be resolved before actually implementing telemedical applications in everyday clinical practice.
Issues such as protection of data privacy as well as ethical and legal aspects require special attention, seen as there are no ubiquitous standards or policies, especially regarding the transmission of data through mobile networks.

Telemedicine can represent a suggestive complement to conventional diagnostic and therapeutic options used in everyday clinical practice.
Rather than a well defined domain, Telemedicine is used as an umbrella term covering a large range and including a huge amount of related terms that are often used interchangeably.

Judging from past developments in telemedicine as well as the current hype, one might foresee that all doctors hereafter will probably be confronted with telemedicine in one way or the other.
Thus, an open yet critical approach to the subject is essential and thorough evaluation is required to successfully implement telemedical applications.

Furthermore, a practically oriented approach is necessary, as well as keeping the patient in the center of attention rather than all focus being on bandwidth and pixel.

Implemented in the right domains, telemedical applications can offer diagnostic, economic and therapeutic advantages as long as we maintain a holistic view of Medicine with the patient always taking center stage.

It can be foreseen that in the near future mobile telemedicine will exceed its current limits and will be implemented in various fields of Medicine.
Mobile phones may have a special function for online consultation, including advice and follow-up for dermatological conditions and a triage system for new and suspicious skin tumors.

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Conflict of interest: The graduand assures that there is no connection between her and any company or product mentioned within the thesis or any company distributing a competitive product.