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E-Health and telemedicine applications in plastic surgery and the treatment of facial palsy

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ABSTRACT

Facial palsy (FP) is a life changing condition with physical, aesthetic, functional and psychosocial consequences, which requires specialized diagnosis, rehabilitation and (surgical) management to improve facial function and reduce its negative effects. Since patients remain in follow-up during their life and often have to travel far to receive treatment, improvements can be made in the field of telemedicine. Telemedicine is a growing field of study in medical practice and several advances have been made in the field of plastic surgery. Especially during the COVID-19 pandemic, considerable experience was gained in this way of consultation. This review provides an overview of current research available in the field of E-Health and M-Health in plastic surgery and for patients with a peripheral facial palsy.

Introduction

Facial palsy (FP) occurs as a result of damage to the facial nerve (n. VII). The facial nerve controls the muscles used for expressing emotions and for creating facial gestures being thus crucial in interpersonal communication [1–4]. The damage to the facial nerve can cause facial asymmetry (both at rest and in movement), weakness of affected muscles, and synkinesis (involuntary movement of muscles due to incorrect regrowth of nerve fibres after injury). This could result in several impairments on physical, aesthetic, functional and psychosocial level. Examples are functional difficulties with lacrimation, salivation, taste, speaking, manipulation of food, oral incontinence, and corneal damage due to absent corneal reflex and psychosocial effects like low self-esteem, anxiety, and depression. Quality-of-life (QoL) may also be reduced [1,2,4–10]. Therefore it is paramount to provide a detailed, focused and objective evaluation of facial asymmetry, so that adequate treatment, rehabilitation and management can be given to improve functional outcomes and reduce negative effects.

The most frequently used observation scales in the treatment of FP are the House-Brackmann score, the Sydney system, the Sunnybrook scale and the eFace grading system [3,5]. The House-Brackman grades only the FP severity, whereas the Sydney-, Sunnybrook- and eFace grading systems also provide more detailed information about symmetry, voluntary movements and synkinesis [3,5].

Due to the COVID-19 pandemic and its impact on public life, health systems worldwide are adapting to supply optimal medical assistance not only to COVID-19 patients, but also to existing patient care. In order to minimize the transmission of the virus, a lot of hospitals and private practices have relied on their e-Health and ICT facilities. Therefore the call for telemedicine applications increases. Telemedicine was first described in the 1970′s and signifies the use of Information Communication Technology (ICT) to improve patient outcomes by increasing access to care and medical information. The WHO defines Telemedicine as followed: “The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities” [11].

Telemedicine is an increasingly popular field of study in several physical and mental conditions and has been associated with increased access and compliance, similar or better quality of life [12–16]. Telemedicine can also be used to follow up surgical wounds postoperatively. This can be useful in several aspects of plastic surgery. Especially this can increase the efficiency of postoperative care in several proce-

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dures, amongst microsurgical operations, the improvement of care coordination and management of burn wounds [26–29,30,32]. It allows for quick inter-physician consults and connects patients with professional expertise without obstructing the accuracy and quality of care provided [36]. The use of video assessment has shown a positive effect on quality of care and rehabilitation outcomes for facial palsy patients [12,17–19]. The quality of the video assessment depends on several technological aspects such as the video and audio quality or the used modality.

All these aspects have been analysed in the literature related to imaging of facial palsy in the last few years [36–37,39,40,43]. Several attempts have been done to optimize imaging in facial palsy. From standard two-dimensional measurements using FACE gram (or the newer Emotrics) software, developed by the Sir Charles Bell Society, to more sophisticated 3D measurements [36,37,40] or even 4D measurements [43].

Since many of the symptoms associated with facial palsy change over time due to nerve function recovery potentially due to therapy (mime therapy, botulinum toxin treatment or surgical options in the form of static or dynamic facial reanimation), or worsen due to the development of synkinesis, patients with FP remain in follow up [1,2,4,8,9]. Since FP is managed and treated only in highly specialized medical facilities, several patients have access issues, mostly due to distance, transportation, time constraints, mobility, frequency of follow-up visits and cost of care. Their physician could make improvements in the field of telemedicine so patients can receive the same standard of care from home, and also minimizing the amount of face-to-face assessments. These problems in combination with the current COVID-19 crisis, causes an increasing call for electronic/mobile health applications, and with fast increasing communication technology, makes this more possible than ever.

A distinction in Telemedicine can be made between “E-Health” and “M-Health,” where E-Health is focussed on video consultations between patient and their physician. But also health services that are offered using Information and communication technology (ICT). In general M-Health is a term used for medical practice and public health supported by mobile devices, which can have partial overlap with E-Health

This narrative review will give an overview of the literature and currently available E-Health and M-Health applications in plastic surgery and in the specialized field of facial palsy treatment, management and legal aspects. These can be used in the above-mentioned context.

E-Health

E-health is “an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the internet and related technologies,” as described by Eysenbach [20]. The application of E-health gives the opportunity to provide information tailored to individual needs, could improve the capability to combine a variety of media to the particular purpose of the treatment while users remain anonymous, even in receiving case specific support from peers and experts [21]. Technology-based interventions have already been a proven tool in weight loss and lead to higher program adherence [22].

The COVID-19 outbreak has resulted in major changes in E-Health application, especially in developed countries and it is likely that this uptake will remain at a higher level even after the pandemic, since patients and providers grow increasingly more accustomed to its use [23].

M-Health

The mobile phone, and specifically the smartphone, could be an ideal candidate for the implementation of therapeutic applications due to several properties such as the integrated camera, portability, accessibility, and in-built Internet connectivity of the device. Furthermore, the availability of smartphones is high, where, 87% of the Dutch population in 2018 and 81% of American population in 2019 owns a smartphone. With an increase in camera quality and processing power, more “apps” with complex functions can be developed, which previously would require a computer [29,30]. Even older generation smartphone cameras can be used for diagnostic purposes in specialized disciplines, as the iPhone 3 G was used in fundus photography [24,25].

Telemedicine in plastic surgery

Table 1 gives an overview of the E-Health applications in current plastic surgical literature. In the systematic review by Vyas et al. [26] twenty-three studies assessing Telemedicine in plastic surgery were evaluated. amongst the included studies that various areas were explored (wound management, burn management, trauma, free-flap care, in cleft lip/palate repair) and all reported improved postoperative monitoring and increased access to expertise while lowering costs [26]. Eight studies reported barriers and limitations to telemedicine applications, including over diagnosis and dependence on telecommunication systems. The authors concluded that current telemedicine advancements provided a worthy adjuvant to the plastic surgical toolkit and stressed the need for high quality evidence to demonstrate clear and reproducible benefits of telemedicine in routine clinical practice [26,27]. An article by Gardiner et al. [28] reviewed twenty-nine studies on plastic surgery and telemedicine (11 trauma/burns, 4 hand, 5 wound care, 5 maxillofacial, 1 digital replantation, 2 free-flap monitoring and 1 technical application),where twenty-eight (96%) of these studies reported beneficial effects (increased access, saved costs) of the use of telemedicine. However only five (17%) studies clearly reported this beneficial effect when compared to standard face-to-face treatment. Fifteen studies (51%) also reported adverse effects, including misdiagnosis, time consumption, training, technical and cost issues [28]. Only four (14%) studies discussed conforming to legal guidelines. Gardiner et al. concluded that there is little critical analysis on risks and benefits of telemedicine although expertise can be facilitated more remotely with increased access to plastic surgical healthcare. The authors also consider legal implications and the need to safely integrate these into daily telemedicine practice [28].

The review by Perera and Chakrabarti [29] shows that M-Health and E-Health advances in plastic surgery have improved the management of wound care, assessment of burns, real-time monitoring of free-flaps and even a range of facial and hand/limb injury consultations in an emergency setting [29–34]. In these, mostly observational studies a teleconsultation with the surgeon provided initial surgical management plans which were only modified in 15% of cases [30]. Hwang and Mun studied the use of the smartphone camera in threatened flap detection and due to early re-exploration increased the salvage rate from 50% to 100% [32]. Next to a shortened response time, another advantage is that this application of ‘real-time’ is that the specialist is consulted easier and provides diagnostic accuracy and prevents unnecessary rides from the surgeon to the hospital to evaluate the flap themselves.

Another use of automated applications to categorize skin tumours remain a controversial field of study, since the diagnostic accuracy of three out of four smart- phone apps failed to identify 30% of true melanomas [35].

Telemedicine in facial palsy treatment

Table 2 gives an overview of the research available on E-Health and M-Health applications in Facial Palsy treatment. The exploratory study by Tan et al. [36] compared video- to face-to-face assessment of the House-Brackmann grade, Sydney system score and Sunnybrook system score. They found similar reliability in all systems between both assessments, even though the two-dimensional nature of the video assessment. However, there was a poor reliability in the assessment of synkinesis and there was insufficient agreement between assessments in both modalities, therefore a strong recommendation to its reliability could not be voiced [36].

One of the major limitations in this study was the use of recorded video assessments. Since only recorded video assessments were used, the

Table 1
Current research available on E-Health and M-Health applications in plastic surgery.

Overview Plastic Surgery Applications		
Author	E-/M-Health	Purpose
Pereraand Chakrabarti [29]	Both	Improvement in management of wound care, burn assessment, real-time monitoring of free-flaps, range of facial and hand/limb injury consultations in emergency setting
Hwang and mun [32]	M-Health	Use of the smartphone camera in threatened flap detection
Hsieh et al. [30]	E-Health	Teleconsultation with surgeon for initial surgical management
Doukas et al. [35]	M-Health	Skin lesion assessment using mobile technology
Ramlakhan and Shang [51]	M-Health	Automated skin lesion classification using mobile phone
Vyas et al. [26]	E-Health	Systematic review of Telemedicine in Plastic surgery and Dermatology
Kantor [27]	M-Health	Letter to the editor: Telemedicine in Plastic surgery
Gardiner and Hartzell [28]	E-Health	Review of applications, limitations and legal pitfalls in plastic surgery

Table 2
Current research available on E-Health and M-Health applications in facial palsy treatment.

Overview Facial Palsy Applications		
Author	E-/M-Health	Purpose
Tan et al. [36]	E-Health	Comparison made in Video- to Face-to-Face asessment of House-Brackmann, Sydney and Sunnybrook grading scales
Ten Harkel et al. [39]	E-Health	Assessment of depth accuracy in RealSense F200 4D camera for low-cost home use
Coulson et al. [40]	E-Health	Assessment of 3D dimensional displacement of normal facial movement
Codari et al. [37]	E-Health	Evaluation of facial asymmetry using stereophotogrammetric (VECTRA) devices
Banks et al. [41,42]	M-Health	Clinician graded facial nerve assessment scale eFACE
Lee et al. [43]	E-Health	Comparing House-Brackmann Scales (HB I & HB II) with Facegram software

physician cannot ask the patient to repeat or alter movements or adjust camera settings, therefore real time assessment provides opportunity [36].

Attempts have been made to assess facial asymmetry in a fast and non-invasive way using the VECTRA M3 stereophotogrammetric system. Providing viable quantative information in diagnosing, treatment planning and evaluation [37]. However such applications proved inept in non-specialized practice, since the VECTRA system is non-portable and very expensive.

Since 2D pictures do provide information on movement, 2D video lacks the anterior-posterior axis, which can potentially lead to biased assessments of faces [39]. There are now commercially available 3D video cameras, which are important in judging faces in a three-dimensional fashion [14–17,19,38]. Ten Harkel et al. [39] explored the possibility of an economically viable telemedicine 3D imaging system for home use. The RealSense F200 4D camera was chosen for its portability, relative low cost and its ability to capture the anterior-posterior axis in facial movement [39,40]. The camera was evaluated on its (depth) accuracy, since this is vital before clinical implementation can be achieved. In a cohort of 34 unilateral FP patients the RealSense camera provided reliable and accurate depth data when capturing faces at rest and in all five key voluntary movements based on the Sunnybrook facial scoring system. The authors conclude that the RealSense camera provides reliable and accurate depth data collection with a reported depth accuracy range of 1.46–1.53 mm at a highest depth accuracy of 1.07 mm at a distance of 35 cm [39]. However, the study did not use an objective analysis method (like the Sunnybrook scale) to determine the facial asymmetry to determine the feasibility of the facial palsy assessment by the RealSense camera. The RealSense D415 camera was also investigated in comparison with the professional 3dMD imaging system in thirty facial palsy patient faces in neutral position. Two observers placed 14 landmarks on the 3dMD and RealSense image assessing the distance between landmarks and found excellent intra- and inter-rater reliability, and a statistically significant difference between a number of the palsy landmark and the respective healthy landmark ($p < 0.05$). Therefore concluding that the RealSense D415 could also be a viable option when compared to the RealSense F200 [39].

Furthermore, in 2014 the eFACE application was designed and validated by Banks et al. [41,42]. This is a comprehensive, electronic and clinician graded facial function scale that assesses a visual scale of facial function using 3 parameters consisting of 5 static, 7 dynamic and 4 synkinesis items [41,42]. It uses smartphone or pc technology and provides relevant data to all practitioners involved. The authors found that the eFACE scores demonstrated very high inter-rater and intra-rater reliability in experienced facial nerve clinicians and that its ease in utility and continuous disfigurement scale provides a tool for facial palsy research and treatment [41,42].

Lee et al. retrospectively reviewed 77 facial videos of FP patients scored by 3 facial nerve specialist using the House-Brackmann Scales (HB I and HB II) and comparing these scores with Facegram software, providing an automated, zone-specific facial analysis tool that could standardize facial paralysis assessment [43].

Legal aspects

Several legal and regulatory challenges have to be faced in the development of telemedicine in daily clinical practice, since telemedicine does not allow for the same patient-healthcare provider interaction as a face-to-face visit where the patient can be traditionally examined and documented. There is also the issue of appropriate reimbursement. Without adequate reimbursement, healthcare providers are confronted with investment obstacles, since telemedicine implementations and practice are costly in money and time [38]. It is extremely difficult to give a general overview of all the legal aspects and regulatory challenges per country, since several aspects are organised on a European or Worldwide level with different laws per country. When looking at the Netherlands and Belgium (countries of origin of the authors group of this article), a specific legal framework for telemedicine does not exist in the Netherlands or in Belgium. The "Inspectorate Healthcare" says that legislation for medical devices are regulated at European level. Requirements are set on products and production. This is different for the involved physicians. In the Dutch BIG Act it is specified which groups of professionals may perform a certain treatment or invasive procedure (referred to as 'reserved acts'). However this "Inspectorate Healthcare" does not state anything about the use of medical technology (e.g. E-Health/M-Health applications). For adequate handling, information protection and privacy of patient/clinician data, nothing is mentioned. It can be postulated that there needs to be a basic qualification to use/implement medical technology in daily practice. However in the Netherlands there is no such statement. Also in the rest of Europe, the laws are quite vague on this matter, which can give problems of there own. Finally, there are legal regulations surrounding it privacy, which also applies to telemedicine [44]. A move towards standardized licensing and regulation across the European Union should provide the adoption of telemedicine technologies and thus remove barriers and increase utilization and innovations.

Discussion

In this review the current state of E-health and Telemedicine Applications in plastic surgery and the Treatment of Facial Palsy was analysed. Most electronic and mobile health applications are focussed on imaging, but lack large-scale application in daily clinical practice [29]. The research by Tan et al. [36] is a first step into adequate video assessment of facial palsy patients. Despite the fact that video assessment of synkinesis has poor reliability and the insufficient agreement between multiple assessments in this study, it is still believed to be a promising tool for the future. A possible explanation could be the differences between 2D and 3D videos. Three-dimensional videos have better properties of detecting synkinesis, which can be enhanced if we apply deep learning and automated 3D video analysis software is developed. In this context, a 3D home application of automatic Sunnybrook scoring of faces or applications such as 3D applicable versions of eFACE or the Facegram software, could prove a welcome addition in increasing specialized access in diagnosing, treating and rehabilitating FP patients.

In an article by Perera et al. the evidence has been reviewed of the increasing capabilities of camera-equipped mobile phones and its application in medical imaging. Of the 235 reviewed articles, most publications arose from the fields of radiology (21%), dermatology (15%), laboratory techniques (clinical chemistry, haematology, microbiology) (15%) and plastic surgery (12%) [29].

M-health has been evaluated in cardiac patients [45,46]. Healthcare professionals, managers and ICT developers all saw benefits in increased monitoring and care at home for patients. Healthcare professionals warned for an overload in data for patients, managers noted difficulties in continued patient motivation and ICT developers noted that reliable devices, applications and software of adequate quality are paramount in the success of M-health in patient care. They also mentioned that applications should be user-friendly, easy to install and intuitive to use [45,46]. Recently Taeger et al. [52] developed an app for mobile phones using the IOS interface to grade facial movement disorders. This could be the next step for mobile smartphone technology to quantify facial disfigurements due to a variety of diseases (for example a peripheral facial palsy). Also such an app could be used to easily measure effects of reconstructive surgery in facial movement disorders [52].

In every instance, the treating physician should be able to respect the user or patient's privacy, storage data securely to prevent access by a third party or unauthorized personnel and informed consent should be obtained [29,47–49].

Future directions of telemedicine applications

To extend the reach of telemedicine in plastic surgery and facial palsy treatment and follow-up, the following actions could be promoted based on the available literature: Professional associations should increase education and resources available to support and encourage telemedicine development, including policies and protocols, which should be easily accessible to health care practitioners; Telemedicine must become an integral part of medical education for physicians and nurses, so the next generation of practitioners can incorporate telemedicine further into their clinical practices. Information on privacy developments in telemedicine must become more available to health care professionals so licenses can be acquired and reimbursement can be adequately obtained [50].

Telemedicine based interventions can be valuable in plastic surgery and in the treatment of facial palsy [30,36–39,41,44–50]. The possibilities on E-Health and M-Health are rapidly growing and improving. Therefore it is paramount to implement these applications in current medical care. Multiple studies in plastic surgery/dermatology investigate the use of the smartphone camera, and since there is much reliance on visual stimuli, applications that judge or easily communicate photos could be of added value [36]. Furthermore, to increase the utility of telemedicine, more randomized controlled trials should be done to find innovative treatment methods that can be implemented as gold standard. Also existing applications should be kept up-to-date to the newest advancements in photo and video resolution, Internet connectivity and data encryption.

Conclusion

Telemedicine applications are being applied in various ways and are increasingly popular. These advances are at the verge of changing the way medical practice is understood. A lot of E- and M-health studies provide excellent examples of how these applications can improve our way of treating patients, however no gold-standard has been set. In the field of facial palsy however, not much has been researched, thus this remains a field of future study.

Declaration of Competing Interests

The authors have nothing to disclose.

CRediT authorship contribution statement

Frank W. de Jongh: Conceptualization, Visualization, Writing – original draft, Writing – review & editing. **Elijah E. Sanches:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing. **Sjaak Pouwels:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing. **Timen.C. ten Harkel:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing. **Koen J.A.O. Ingels:** Conceptualization, Visualization, Writing – original draft, Writing – review & editing.

Research involving human participants and/or animals

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