SMART WEARABLE MEDICAL DEVICES – THE NEXT STEP IN PROVIDING AFFORDABLE SUPPORT FOR DERMATOLOGY PRACTICE

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Summary

The prevalence of skin disorders is increasing worldwide due to, several factors like the changing environment and climate, or to an inappropriate lifestyle. Skin disorders have major and long-term negative implications at individual and national healthcare systems levels. Smart wearable medical devices are more and more integrated in dermatology practice because they can facilitate a proactive approach of the healthcare, a better monitoring, and improved diagnosis and treatments. This paper aims to present the benefits brought by the use on large scale of the smart wearable devices in dermatology. After a short review of the particularities of the wearable devices employed in healthcare, the practical implications of the implementation in dermatology practice are put forward. A brief look over some of the current and future smart wearable devices that sustain dermatological services demonstrates their potential of transforming the current medical practice. Continuous monitoring, easier access to a huge amount of heterogeneous collected data, an effective support for diagnose and treatment decision making, and improved engagement of the patients are only some of the features that prove the undoubted role of these emerging devices in dermatology practice.

Key words: *smart wearable devices, sensors, dermatology, monitoring, diagnosis*

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Introduction

Nowadays, the skin disorders are among the major sources of the current burden of the worldwide national health services, also implying high expenditure at individual level [1]. Most of the skin diseases have a strong negative impact on the quality of patients' life, and some of them can lead to permanent disabilities or death. The continuous growth and ageing of the global population, the dynamics of environment and health risk factors (like climate changes) impose an increased demand of financial, human, scientific and technological resources for sustaining and improving dermatology practice.

Therefore, it is compulsory to integrate in current and future dermatology practice newer technologies and business models which have the potential to provide an efficient and affordable support. Some of the major challenges in healthcare can be handled by Internet of

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Things (IoT) technologies, including smart wearable medical devices able to sustain more accurate, real-time, cost-effective and comprehensive monitoring and diagnosis.

This paper aims to briefly present the main characteristics of smart wearable medical devices and to emphasise their extended capacity to transform the dermatology practice. In order to demonstrate their opportunities, some examples of the newest smart wearable medical devices are brought in.

Wearable Medical Devices: Features and Trends

The ***Internet of Things (IoT)*** is the network of physical objects or "things" embedded with electronic devices, software technologies, sensors and connecting networks, which facilitates data acquisition and exchange. The IoT is defined as "the network of physical objects which are supported by embedded technology for data communication and sensors to interact with both internal and external objects states and the environment" [2]. IoT provides the possibility of healthcare monitoring using wearable devices.

Wearable devices belong to a category of electronic devices that can be mated with human skin (placed on the epidermis, inserted through the skin or body orifices for measuring [3]) or worn on the body, either as an accessory or included in the material used for clothing. Examples of wearable devices are smartwatches, wristbands, hearing aids, electronic/optical tattoos, head-mounted displays, subcutaneous sensors, electronic footwear, or smart cloths (with electronic textiles). ***Wearable medical devices*** are wearables incorporated in clothing, accessories, skin surface or close environment that monitorize, provide electronic alerts, perceive physical and biochemical information, or deliver drugs [4].

Wearable medical devices are used for enabling real-time data acquisition of "electrophysiological, biochemical or environmental signals and communication for continuously and closely patient monitoring, without interrupting or limiting the user's motions" [6]. Sensors integrated in wearable devices include inertial measurement units, optical sensors, chemical probes, electrodes, temperature sensors, microphones, shock detectors, strain gauges, and pressure sensors [7]. Motion trackers, and vital parameters are the most important elements in health monitoring [8].

Medical sensors produce gross values of data that are transmitted wirelessly to a transmitter-centered central unit. This transmitter unit processes raw data and converts them into significant metadata [9]. The storing of a huge amount of medical data in data bases and the exchanging of information with other devices are facilitated. Data obtained from multiple wearable devices are routing to a body area network that can transmit the medical data to the Internet through Bluetooth, Wi-Fi LTE, 3G, 4G, or 5G connection for further analyses or feedback from a healthcare provider [5].

The medical wearable devices that have a robust and soft contact with the skin to deliver a range of functionalities have to be flexible, stretchable, and to provide accurate sensing and biometrics required for health monitoring in a noninvasively way. Flexible smart wearable devices "can be configured to make conformal contact with epidermal, ocular, and dental interfaces to collect biochemical or electrophysiological signals" [5].

The restrictions on wearable devices refer to the size, battery life, and weight. Medical wearables devices must provide on board sensors and a large amount of computing power into a small package [10].

"***Smart wearable devices*** (a merge between a sensor and a microcontroller) leverage the IoT potential in the healthcare area by stimulating a proactive preventive care, a more accurate diagnostic and a more appropriate evaluation of the treatment results" [11]. These wearable medical devices are developed for both monitoring and diagnostic functions and can be placed at various locations on the human body (ex. electrodes for electrocardiography, electromyography, devices for monitoring of blood pressure, temperature, glucose, lactate, pH, Na, K, blood oxygenation, skin hydration or evolution of wounds) [12].

Emerging trends concerning the evolution of wearable medical devices

"Smart wearables are becoming increasingly pervasive driven by the continuous miniaturization of electronics; advances in sensor technology, computing power and connectivity; they demonstrate an even stronger capability to embed intelligence in electronic (and photonic) components and systems, ultimately coupled by a reduction in the price of components. From phase 1 when they were accessary type devices, through phase 2, textile-integrated, with integration of various electronics, they evolved to phase 3 as skin patchable devices and finally to phase 4, as body implantable, conformal to organs and safe for the human body. [13].

Gartner estimates that the number of wearable devices generated worldwide is expected to grow from 275 million units in 2016 to 477 million units in 2020, generating a revenue of $61.7 billion [14]. The Global Mobile Data Traffic Forecast by Cisco predicts that, by 2020, their number will increase to 601 million globally [15]. According to a survey conducted by Ericsson Consumer Lab, 60% of the participants consider that, in next five years, biomedical sensors would be commonly used [16].

Medical wearable devices are moving towards the miniaturization of their size, the increased facility of measuring of more vital signs, secure and reliable data transmission. [5].

Implications of using smart wearable medical devices in dermatology

Dermatology has a strong visual feature that stands primarily upon the visual observation of the current state of the skin which, more than the other organs, is appropriate both for being monitorized, and to be a medium towards other organs that can be monitorized with smart wearable medical devices.

Some of the main benefits of using the smart wearable medical devices on large-scale in dermatology practice are:

- the continuous monitoring and access to real-time updated data support dermatologists in a better decision making and diagnosis;
- many hospitalizations and regular examinations can be avoided;
- the access to particular health parameters collected through smart wearable devices allow the dermatologists to evaluate continuously skin properties (like hydratation, temperature, blood oxygen level, wound-healing, skin mechanics) or various disease biomarkers measured in sweat and to provide a timely personalized treatment;
- the health specialists can be notified almost instantly whenever an abnormal event occurs by receiving current data on their smartphones;
- the underserved population (like people living in isolated areas or untrasportable ones) can be monitorized and treated remotely;
- being non-invasive, smart wearable medical devices have a positive impact on patients' attitude and behaviour regarding the treatment of the skin disorder;
- the outcomes obtained after a specific use of a smart wearable medical device in a skin disease treatment or a wound or post surgery healing might support the deployment of improved medicines, dressings, patches or devices.

Examples of smart wearable medical devices in current and future dermatology practice

a) ***The smart bandage that helps heal wounds and administers antibiotics on its own [17]***

The researchers from Tufts University in Massachusetts have invented a smart bandage with sensors and processor that constantly checks how the wound progresses and automatically administers the required dose of drugs. The smart bandage has a special processor and sensors integrated that constantly monitor how the wound heals.With the help of special sensors that analyze the temperature and pH of the wound, smart bandage can detect signs of infection or inflammation in time. Thus, it will administer directly to the skin the antibiotics that are needed. [17]

The new generation of bangs will be used especially to treat persistent wounds that heal very hard. It is the case of burns, but also of the injuries suffered by diabetics. Of course, there are other situations where chronic wounds can not be cured, because the skin does not have the normal regenerative capacity.

Another advantage of the new type of patch is that it administers the necessary drugs alone, without the need for frequent care from doctors or caregivers. In addition, it stimulates the natural healing process.

An intelligent bandage has several components, including: (i) sensors for pH and temperature measurement; (ii) flexible microheater, (iii) carriers of thermally responsive drugs incorporated into a hydrogel patch; (iv) wireless electronics for reading data from sensors and for triggering and controlling the thermal actuation system, if necessary. [18]

b) ***A patch with nanocip helps heal wounds through genetic reprogramming [19]***

The researchers from Ohio State University, United States designed a nanochip reprogramming cells to help the body heal. The new technology is called Tissue Nanotransfection and involves touching the affected tissue with a special patch with an inserted a nanochip of a coin size. The patch is held on the skin for only one second, then it is removed (at that point, cell reprogramming begins), and the skin will heal itself in record time.

The moment it is glued to the skin, a strong and focused electric field is applied along the device that allows the nanochip to inject into the skin cells a genetic code so that they can turn into any type of cell, stimulating the restoration of the destroyed blood vessels.

c) ***Sensitive sensor for measuring exposure to UV radiation [20]***

UV radiation is essential for the production of D vitamin and beneficial to human health, but excessive UV exposure has many associated risk factors, including skin cancer and photosensitisation. The acute effects of excessive UVA and UVB exposure are usually short-lived and reversible. Such effects include erythema, darkening of the pigment and sunburn. Prolonged exposure even at sub-eritemal UV doses causes thickening and epidermal degradation of keratinocytes, elastin, collagen and blood vessels, leading to premature aging of the skin.

Recently, an ultra-thin, expandable and breathable ***wearable UV sensor*** has been developed to accurately quantify UV exposure and quantify solar protection. The UV sensor is designed to match the surface of the skin and to provide a soft expandable interface. This sensor contains dyes that change color when exposed to UV radiation. This color change is then quantified using a smartphone and quantisation algorithm.

The functionality of the device has been demonstrated in various real-life activities, including swimming in the ocean, beach activities, showers and compatibility with sunscreen and skin care products.

d) ***sKan - Wearable device for diagnosing skin cancer [21]***

Diagnosis of skin cancer will soon be possible with the sKan portable device. The device was invented by four young engineers at McMaster University in Ontario, Canada.

The device is small, portable, and can be handled very easily with one hand. In addition, it is made of cheap and easy-to-buy materials, so the device will be affordable as it comes out on the market. The device has temperature sensors that analyze skin temperature and thus can detect early melanoma. Skin affected by melanoma will heat up much faster than the rest of the skin when exposed to a cold source. This is exactly the principle that sKan works.

SKan has thermistors to monitor the heat emissions of cancer cells in real time. The heat map it creates shows that cells recover faster from heat shock, indicating the presence of melanoma.

e) ***Sunee cap - the prototype of a smart cap [22]***

The Sunee cap prototype is one of the winning projects of the InnovationLabs 2017 edition, made by a group of Romanian students. The inventors have chosen to choose this outfit because its use is natural, people anyway use a cap to protect themselves from the sun.

The cap includes 3 sensors (one for ultraviolet rays, one for temperature and an accelerometer). The UV sensor is sensitive to UVA and UVB radiation, and the natural head cap position allows the sensor to be exposed to the sun in the most effective way to measure radiation exposure to other devices such as bracelets or clocks for example. The accelerometer is useful because it shows whether the cap is carried by the child, whether it is moving or was simply forgotten in the sun.

The Sunee cap is connected to an app, which is currently only compatible with Android 4.4 and higher (or Kitkat). The interface of the application is designed to be as user-friendly and easy to use by both parents and children. It contains a page with statistics on the last days or weeks on sun exposure, but also an educational page. Here, users will find information on the risk of solar radiation, effective protection methods and complications that skin burns can cause, such as skin cancer.

f) ***Transdermal therapy [23]***

Transdermal therapy is a method of transporting active medical substances through the dermis, allowing fast and painless delivery of active agents to the affected organ or tissue without causing side effects and without overloading other organs: kidney, stomach, liver, and gastrointestinal tract intestinal.

The phyto-patch is used in this therapy. Body phyto-patch are designed for recovery and preservation of health. First of all, in the composition of phyto-patch we find active substances – complex of valuable herbs and natural ingredients. Secondly, active drug substances penetrate the body in a natural and safe way - through the skin.

g) ***Modernist masks for wrinkle removal***

MAPO Opera - Wired Beam Mask is the world's first smart beauty mask. Wired Beauty has worked with the prestigious French-Japanese design studio A + A Cooren to refine the minimalist prototype. This 3D mask is made of soft silicone and is provided with bio-moisture sensors that measure skin moisture levels in real time. Information is passed to an application that looks for the health of the wearer's skin and provides recommendations for skin care. [24]

iDerma promoted by Apira Science, is the most advanced available phototherapy device that can be worn covering the face completely. iDerma has been developed to improve the overall skin condition to make the skin look lighter and more radiant and to diminish the appearance of fine lines, facial wrinkles and wrinkles. It has moisture bio-sensors that measure skin hydration levels in real time. The collected information is sent to an app that analysis and provides skincare recommendations. The mask can also heat up to allow better delivery of moisturisers and anti-ageing serums into the epidermis. [24]

Conclusions

Even some skin disorders have no severe health deterioratins or consequences, others can become life-threatening if they are not early diagnosed and adequate treated and monitorized.

Sustainable, highly sensitive, reliable medical monitoring devices are required for monitoritoring the human bio-signals in a non-invasive manner and skin-conforming. Flexible and wearable sensors based on nano/micro-materials with unique sensing capabilities are used for detection of physical and electro-physiological patients' vital signs.

Basically, a smart wearable medical device collects non-intrusively data from the patient, transmits it wireless to a storage environment where it is analysed and processed, becoming accessible for scientific assess and use.

Continuously monitoring of the skin disorders, of their evolution, of the efficiency of the treatment, the provided support for decision-making regarding a personalized therapeutic protocol, opportunities for a better identifying of improved health technologies and medicines are only some benefits brought by the smart wearable devices.

The use of these emerging technologies in dermatology practice is undoubtedly a next step for acquiring increased outcomes from the point of view of dermatologists, health professionists, patients, and national healthcare systems.

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Conflict of interest

NONE DECLARED

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