Fingerprint Recognition Influenced by Skin Diseases

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Abstract

This article is devoted to different skin diseases on fingertips which have an impact to the process of fingerprint acquirement or recognition. There are many people, who suffer under such dermatologic diseases and are therefore excluded from the set of users of a biometric system. The classification of skin diseases is made from the medical point of view. This classification is followed by the description of acquired images from the point of view of digital processing.

Keywords: *fingerprint recognition, skin disease, dermatology, papillary line, biometrics.*

1. Introduction

Skin diseases represent a very important, but often neglected factor of the fingerprint acquirement. It is impossible to say in general how many people suffer from skin diseases, because there are so many various skin diseases – please refer e.g. to [1][2][3][4][5], but we must admit that such diseases are present in our society. When discussing whether the fingerprint recognition technology is a perfect solution capable to resolve all our security problems, we should always keep in mind those potential users who suffer from some skin disease.

In the following text, several skin diseases are introduced from the medical point of view, which attack hand palms and fingertips. This description is followed by an analysis of acquired fingerprint images from the point of view of digital processing.

The situation after successful recovery of a potential user from such skin diseases is, however, very important for the possible further use of fingerprint recognition devices. If the disease has attacked and destroyed the structure of papillary lines in the epidermis layer of the skin, the papillary lines will not grow in the same form as before (if at all) and therefore such user could be restricted in his/her future life by being excluded from the use of fingerprint recognition systems, though his fingers don't have any symptoms of a skin disease any more.

2. Skin diseases

In the process of fingerprint image acquirement, the skin structure on the fingertip is scanned. Therefore we should know basics of our skin structure to understand better why for example skin diseases might have an influence on the acquirement process. Skin is a remarkable organ of the body, which is able to perform various vital functions. It can mould to different shapes, stretch and harden, but can also feel a delicate touch, pain, pressure, hot and cold, and is an effective communicator between the outside environment and the brain.

Skin makes up to 12-15% of an adult's body weight. Each square centimeter has 6 million cells, 5,000 sensory points, 100 sweat glands and 15 sebaceous glands. It consists of three layers (see Figure 1) [13]: *epidermis* (the outer layer), *dermis* ("true skin") and subcutaneous (fat) layer.

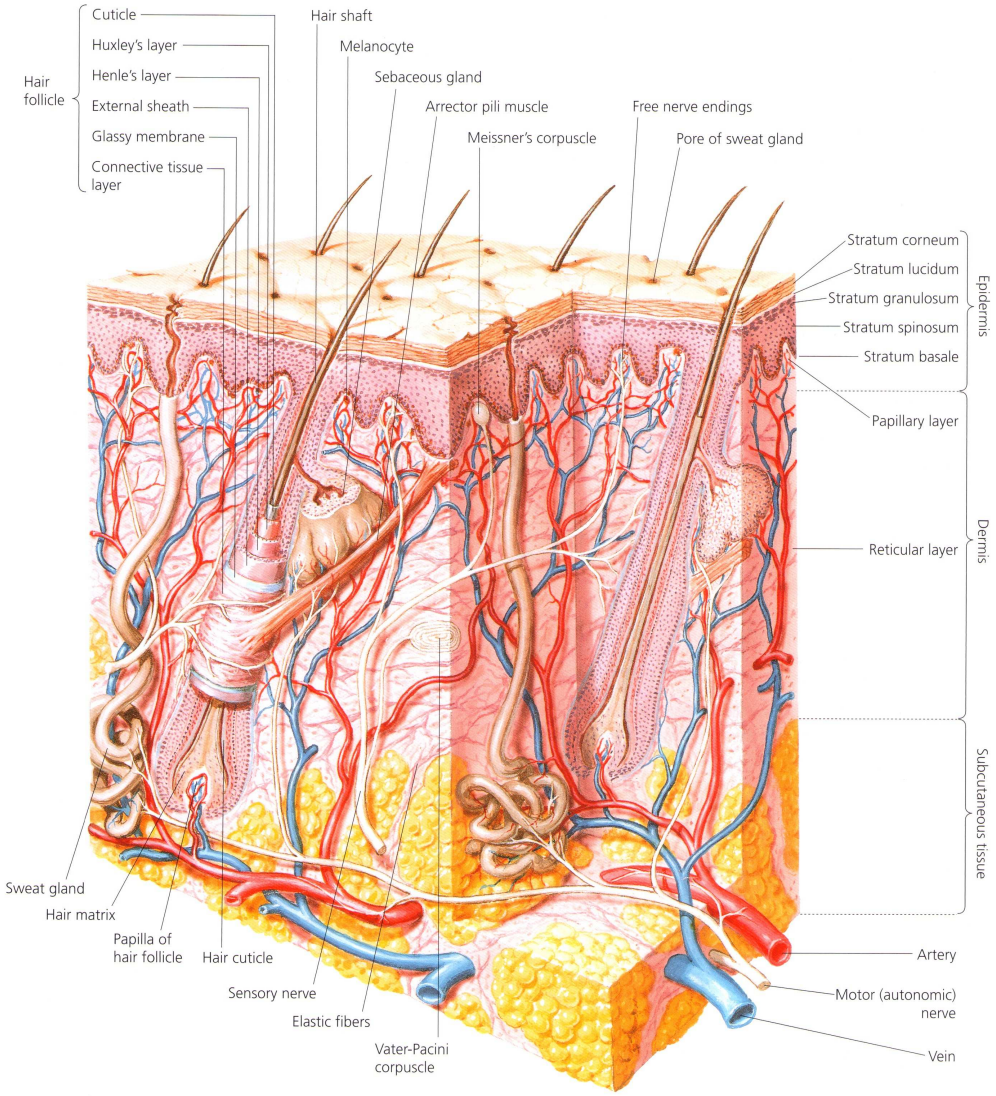

Figure 1. Skin structure [5].

Skin is constantly being regenerated. A skin cell starts its life at the lower layer of the skin (the basal layer of the dermis), which is supplied with blood vessels and nerve endings. The cell migrates upward for about two weeks until it reaches the bottom portion of the epidermis, which is the outermost skin layer l' the papillary lines are placed here. The epidermis is not supplied with blood vessels, but has nerve endings. For another 2 weeks, the cell undergoes a series of changes in the epidermis, gradually flattening out and moving toward the surface. Then it dies and is shed.

There are six skin functions [13]:

- *Sensation* – the nerve endings in the skin identify touch, heat, cold, pain and light pressure.
- *Heat regulation* – the skin helps to regulate the body temperature by sweating to cool the body down when it overheats and by shivering creating "goose bumps" when it is cold. Shivering closes the pores. The tiny hair that stands on end traps warm air and thus helps keep the body warm.
- *Absorption* – absorption of ultraviolet rays from the sun helps to form vitamin D in the body, which is vital for bone formation. Some creams, essential oils and medicines (e.g. anti-smoking patches) can also be absorbed through the skin into the blood stream.
- *Protection* – the skin protects the body from ultraviolet light – too much of it is harmful to the body – by producing a pigment called melanin. It also protects us from the invasion of bacteria and germs by forming an acid mantle (formed by the skin sebum and sweat). This barrier also prevents moisture loss.
- *Excretion* – waste products and toxins are eliminated from the body through the sweat glands. It is a very important function which helps to keep the body "clean" from the inside.
- Secretion – sebum and sweat are secreted onto the skin surface. The sebum keeps the skin lubricated and soft, and the sweat combines with the sebum to form an acid mantle which creates the right pH-balance for the skin to fight off infection.

There are a lot of skin diseases, which can affect palms and fingers. We find plenty of skin diseases including description of their influence on the structure and color of the skin in specialized medical literature, e.g. [4][5][6][7][8][9]. In following chapters we describe some of these diseases together with photographs. These clearly show that these diseases may cause many problems in automatic biometric systems.

The fingerprint recognition systems are usually used only for adults. There is almost no information from appropriate tests with children. Although we know that papillary lines emerge on infant's fingers already in the mother's uterus [10], i.e. we might be able to recognize the fingerprints of infants, the common fingerprint recognition systems are suitable for adults only (due to the area and resolution of fingerprint sensors, etc.). It should not be forgotten that a skin disease in early childhood could have an influence on the skin in adult years (example is incontinentia pigmenti [11] on a small child hand), i.e. there could be some problems with fingerprint acquirement caused by such skin disease in a young age.

The subcategory of skin diseases affecting only the skin color are the least dangerous for the quality of the fingerprint image. In fact, only one fingerprint technology can be considered as sensitive to such diseases – the optical technology [12], but if FTIR-based optical sensors are used, the change of skin color may have no influence on the quality of the resulting images. The case of the other two subcategories (influence of skin structure and combination of influence of skin color and structure) is different. If the structure of papillary lines has changed, it is often impossible to recognize the original curvatures of papillary lines and therefore it is impossible to decide whether the claimed identity is the user's identity. Unfortunately, there are many such skin diseases which attack papillary line structure. Nearly all sensor technologies, namely optical, capacitive, e-field, electro-optical, pressure sensitive

and thermal are exposed to such risk [12]. Only one sensor technology is missing here – the ultrasound technology. This technology has an advantage: the ultrasound waves can penetrate under the upper skin layer to the curvatures in epidermis forming the papillary lines structures and therefore it might be possible to reconstruct the real fingerprint image, but only if the disease has not attacked this underlying structure. If yes, there is no chance to get an original papillary lines structure.

The situation after successful recovery of a potential user from such skin diseases is, however, very important for the possible further use of fingerprint recognition devices. If the disease has attacked and destroyed the structure of papillary lines in the epidermis layer of the skin, the papillary lines will not grow in the same form as before (if at all) and therefore such user could be restricted in his/her future life by being excluded from the use of fingerprint recognition systems, though his fingers don't have any symptoms of a skin disease any more.

2.1. Diseases Causing Histopathological Changes of Epidermis and Dermis

These diseases may cause problems for the most types of sensors.

Hand eczema [5][8] is an inflammatory non-infectious long-lasting disease with relapsing course. It is one of the most common problems encountered by the dermatologist. Hand dermatitis causes discomfort and embarrassment and, because of its locations, interferes significantly with normal daily activities. Hand dermatitis is common in industrial occupations. The prevalence of hand eczema was approximately 5.4% and was twice as common in females as in males. The most common type of hand eczema was irritant contact dermatitis (35%), followed by atopic eczema (22°), and allergic contact dermatitis (19%). The most common contact allergies were to nickel, cobalt, fragnance mix, balsam of Peru, and colophony. Hand eczema was more common among people reporting occupational exposure. The most harmful exposure was to chemicals, water and detergents, dust, and dry dirt.

Fingertip eczema [5] is very dry, chronic form of eczema of the palmar surface of the fingertips, it may be result of an allergic reaction or may occur in children and adults as an isolated phenomenon of unknown cause. One finger or several fingers may be involved. Initially the skin may be moist and then become dry, cracked, and scaly. The skin peels from the fingertips distally, exposing a very dry, red, cracked, fissured, tender, or painful surface without skin lines – see Figure 2.

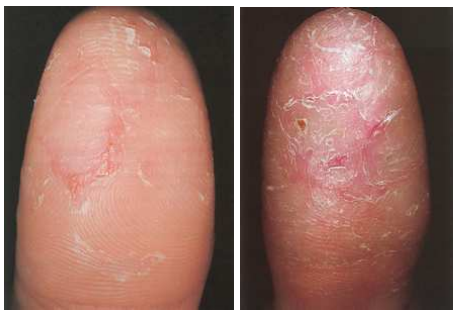

Figure 2. Fingertip eczema [5].

Pomfolyx (*dishydrosis*) [4] is a distinctive reaction pattern of unknown etiology presenting as symmetric vesicular hand and foot dermatitis. Itching precedes the appearance of vesicles on the palms and sides of the fingers. The skin may be red and wet. The vesicles slowly resolve and are replaced by rings of scale. Chronic eczematous changes with erythema, scaling, and lichenification may follow.

Tinea of the palm [5][8] is dry, diffuse, keratotic form of tinea. The dry keratotic form may be asymptomatic and the patient may be unaware of the infection, attributing the dry, thick, scaly surface to hard physical labor. It is frequently seen in assotiation with tinea pedis which prevalence is 10 to 30%.

Pyoderma [8] is a sign of bacterial infection of the skin. It is caused by Staphylococcus aureus and Streptococcus pyogenes. Some people are more susceptible to these diseases (such as diabetics, alcoholics, etc.) - see Figure 3.

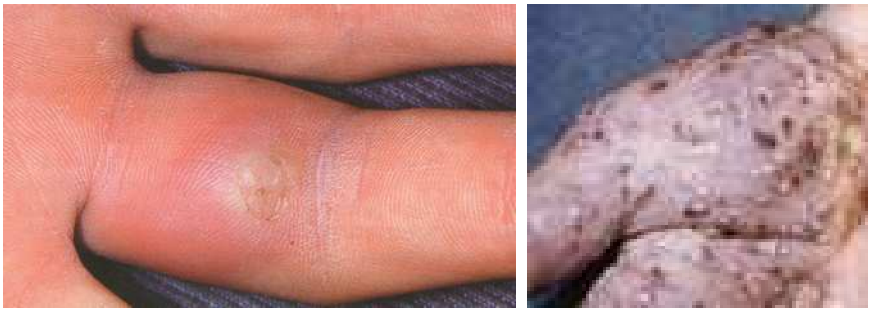

Figure 3. Abscess on finger of patient with diabetes [4] and pyoderma [9].

Pitted keratolysis [5] is a disease mimicking tinea, especially for people who swelter and wear rubber gloves in the hot, humid environment. Hyperhydrosis is the most frequently observed symptom. The disease is bacterial in origin, characterized by many circular or longitudinal, punched out depressions in the skin surface. The eruption is limited to the stratum corneum.

Keratolysis exfoliativa [5] is a common, chronic, asymptomatic, noninflamatory, bilateral peeling of the palms of the hands. Its cause is unknown. The eruption is most common during the summer months and is often associated with sweaty palms and soles. It is characterized by scaling and peeling, the central area becomes slightly red and tender.

Lichen planus [8] is quite common, unique inflammatory cutaneous and mucous membrane reaction pattern of unknown etiology. LP of the palm and soles generally occurs as an isolated phenomenon. The lesions are papules aggregated into semitranslucent plaques with globular waxy surface, ulceration may occur.

Acanthosis nigricans [4][6] is non-specific reaction pattern that may accompany obesity, diabetes, tumors. AN is classified into benign and malignant forms. In all cases the disease presents with symmetric, brown thickening of the skin. During the process there is papillary hypertrophy, hyperkeratosis, and increased number of melanocytes in the epidermis.

Pyogenic granuloma [5] is a benign acquired vascular lesion of the skin that is common in children and young adults. It often appears as a response to an injury or hormonal factors. Lesions are small rapidly growing, yellow-to-bright red, dome-shaped.

Systemic sclerosis [6][8] is a chronic autoimmune disease characterized by sclerosis of the skin or other organs. Emergence of acrosclerosis is decisive for fingerprinting. Initially the skin is infused with edema mainly affecting hands. With the progressive edema stiff skin appears and necrosis of fingers may form. The disease leads to sclerodactyly with contractures of the fingers. For more than 90% of patients is typical Raynaud's phenomenon (see below). The typical patient is a woman over 50 years of age.

Raynaud's phenomenon [5][6][8] represents an episodic vasoconstriction of the digital arteries and arterioles that is precipitated by cold and stress. It is much more common in women. There are three stages during a single episode: pallor (white), cyanosis (blue), and hyperemia (red). Estimates of the prevalence of Raynaud's phenomenon ranged between 4.7 - 21% for women and 3.2-16% for men.

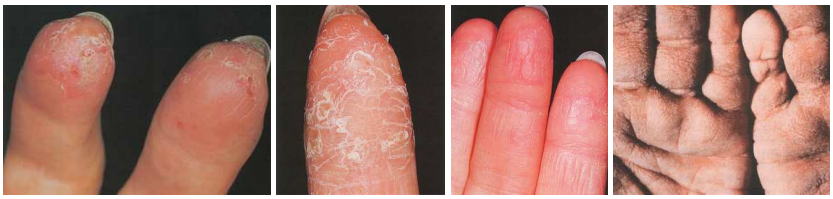

Figure 4. Different types of eczema [5] (3× left) and acanthosis nigricans [4] (right).

Drug induced skin reactions [5] are among the most common adverse drug reactions. They occur in many forms and can mimic virtually any dermatosis. Occur in 2-3% of hospitalized patients. Sulfonamides, NSAIDs and anticonvulsants are most often applied in the etiology.

2.2. Diseases Causing Skin Discoloration

These diseases are focused mainly on optical sensors.

Hand, foot, and mouth disease (HFMD) [4][5] is contagious enteroviral infection occuring primarily in children and characterized by a vesicular palmoplantar eruption. The skin lesions begin as red macules that rapidly become pale, white, oval vesicles with red areola.

Xantomas [5][6][8] are lipid deposits in the skin and tendons that occur secondary to a lipid abnormality. These localized deposits are yellow and are frequently very firm.

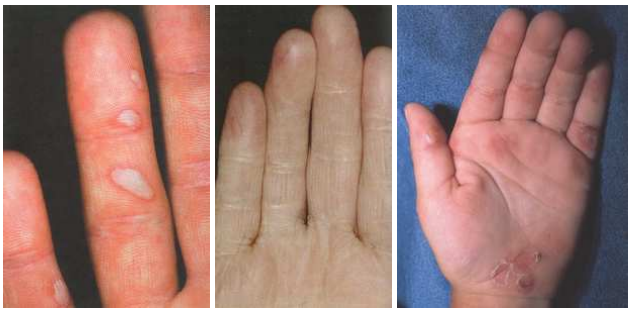

Figure 5. Hand, foot and mouth syndrome [4]; xantomas [6]; epidermolysis bullosa [7].

Scarlet fever (*scarlatina*) [5][8] is contagious disease produced by streptococcal, erythrogenic toxin. It is most common in children (ages 1 to 10 years). In the ending stages of the disease large sheats of epidermis may be shed from the palms in glovelike cast, exposing new tender and red epidermis beneath.

Scabies [7][8] is highly contagious disease caused by the mite Sarcoptes scabiei. It is characterized by red papules, vesicles and crusts located usually on the areas with tender skin, palms and soles especially in infants included.

Secondary syphilis [6][8] is characterized by mucocutaneous lesions, which may assume a variety of shapes, including round, elliptic, or annular. The color is characteristic, resembling a „clean-cut ham“ or having a copery tint.

2.3. Diseases Causing Histopathological Changes in Junction of Epidermis and Dermis

These disease are focused mainly on ultrasonic sensors, the diagnosis also belong to the first group.

Hand eczema – particularly chronic forms (see above).

Warts (*verruca vulgaris*) [8] are benign epidermal neoplasms that are caused by human papilloma viruses (HPVs). Warts commonly appear at sites of trauma, on the hand, in periungual regions. HPVs induce hyperplasia and hyperkeratosis.

Psoriasis [6][7][8] is characterized by scaly papules and plaques. IT occurs in 1% to 3% of the population. The disease is transmitted genetically, environmental factors are needed to precipitate the disease. The disease is lifelong and characterized by chronic, recurrent exacerbations and remissions that are emotionally and physically debilitating. Psoriasis of the palms and fingertips is characterized by red plaques with thick brown scale and may be indistinguishable from chronic eczema.

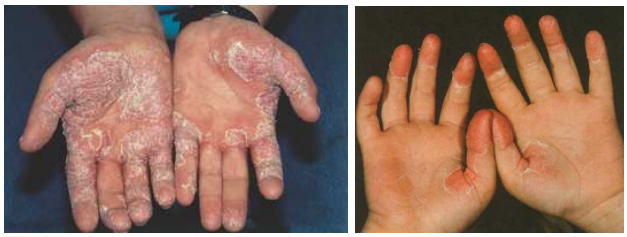

Figure 6. Psoriasis [7]; scarlet fever [5].

Systemic lupus erytematosus (SLE) [5] is a multisystem disease of unknown origin characterized by production of numerous diverse of antibodies that cause several combinations of clinical signs, symptoms and laboratory abnormalities. The prevalence of LE in North America and nothern Europe is about 40 per 100,000 population. In the case of acute cutaneous LE indurated erythematous lesions may be presented on palms.

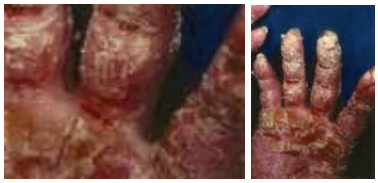

Figure 7. Psoriasis vulgaris [9].

Epidermolysis bullosa [6][7] is a term given to groups of genetic diseases in which minor trauma causes noninflammatory blistering (mechanobullosus diseases). Repetitive trauma may lead to a mitten-like deformity with digits encased in an epidermal „cocoon“. These diseases are classified as scarring and nonscarring and histologically by the level of blister formation. Approximately 50 epidermolysis cases occur per million live births in the United States.

3. Concrete cases of skin diseases on fingerprints

We have acquired fingerprints from patients suffering under different skin diseases. We have used a set for clean fingerprinting using a chemical way for fingerprint acquirement on a special dactyloscopic paper.

Concrete examples of selected skin diseases from our collection could be seen in figures 8 till 10. It is a good illustration for the difficulty, which is caused by a skin disease for a fingerprint recognition system. It is nearly impossible to see any papillary line (ridge) in the images, therefore the image enhancement algorithm in fingerprint recognition system is unable to reconstruct the papillary lines structures and the image could not be processed further any more. The quality of such image is very low – due to different methodologies for estimation of the fingerprint quality, i.e. the image will be rejected at the beginning of the process. Indeed, this situation is very bad for the user – he cannot use the biometric system, his physical identity has to be checked in another way.

The most common skin diseases, which we collected, are: psoriasis, atopic eczema, verruca vulgaris and pulpitis sicca. The probability of occurrence of other skin diseases war lower. However the quality of these other skin diseases, which we collected, was comparable with the types shown in the figures 8 till 10. In the most cases, nearly no papillary lines (ridges) are identifiable, i.e. such fingerprints are not suitable for further processing.

Figure 8. Fingerprint with warts (verruca vulgaris).

Figure 9. Fingerprints with atopic eczema (different people).

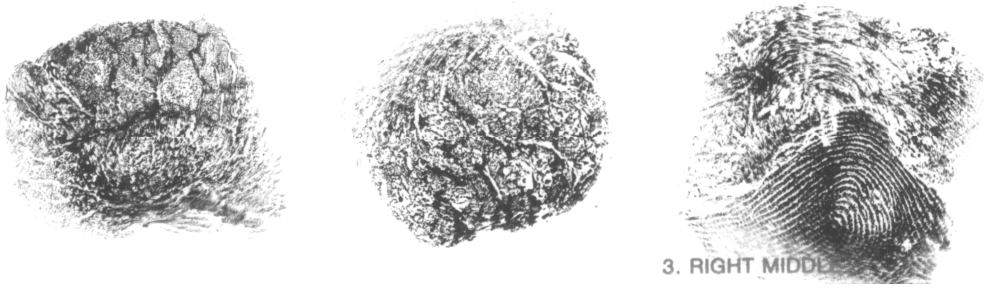

Figure 10. Fingerprints with psoriasis (different people).

4. Conclusion

It is clear from each subsection that either the color of the skin or the structure of papillary lines on the fingertip could be influenced. If only the color has changed, some of optical fingerprint scanners might be influenced and so this change is not crucial. On the other hand, the change of skin structure is very significant, because if papillary lines are damaged, it is impossible to find the minutiae and therefore to recognize the person. If we are unable to recognize/enroll a person, then such person cannot use the biometric system based on the fingerprint recognition technology, and therefore the implementing company has a big

problem – how to authorize such person, if they don't want to use PINs (Personal Identification Numbers) or other authorization methods.

Some of these diseases are only temporary, i.e. after the healing of such disease, the papillary line structure or color is restored and the user is again able to use his/her fingers for the fingerprint recognition in authorization tasks in security systems. However, some diseases leave irrecoverable finger damage restraining a new growth of papillary lines and respective user is then unable to use his/her fingerprints for appropriate recognition tasks in automated fingerprint security systems.

We prepare new collection of fingerprints with skin diseases from patients, oriented not only on dactyloscopic fingerprints, but also on live fingerprints from different fingerprint scanners. The resulting images will be used for quality assessment and if the quality will be acceptable, for minutiae extraction and comparison based on minutiae. Maybe, we will consider other methods, based not only on minutiae, but on correlation or other methods as well.

Acknowledgement

This research has been done under support of the following grants: "*Secured, reliable and adaptive computer systems*", FIT-S-10-1 (CZ), "*Security-Oriented Research in Information Technology*", MSM0021630528 (CZ) and by the project "*Information Technology in Biomedical Engineering*", GD102/09/H083 (CZ).

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