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Embryogenesis and Application of Fingerprints- a review

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ABSTRACT

Fingerprint is an impression made by the friction ridges that are almost parallel at constant crest to crest wavelength. The pattern is dominated by central features, such as whorls, loops, arches and triradii. Fingerprints have been used for several decades in forensic and medical sciences. The fingerprints characteristics such uniqueness, consistency and universality are the main features that are used by forensic experts in identification processes, are well developed during intra-uterine life. Understanding embryogenesis of fingerprints is essential in linking its features to some disease conditions. The purpose of this review was to highlight information regarding establishment, formation, hypotheses and factors affecting fingerprints. Applications of the fingerprints in forensic and medical sciences were also highlighted. Both environmental (in utero) and genetic factors have role to play in the formation of the fingerprints. The primary role of fingerprints is personal identification; these can be achieved through revealing sex, ethnicity, diet and lifestyle of an individual. In another perspective the fingerprints can be used as tools in diagnosis and ascertaining presence of disease conditions, however, this is population specific.

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Introduction

Fingerprint is an impression made by the friction ridges that are almost parallel at constant crest to crest wavelength. The pattern is dominated by central features, such as whorls, loops, arches and triradii. [1] Clear inspection reveals dozens of other imperfections such as ridge endings, ridge bifurcations, island ridges etc. The type and relative geometry of these dislocations form the bases of the uniqueness of the fingerprints. [1, 2]The uniqueness and consistency of the fingerprints throughout life, are some of the features used for personal identification. [2, 3] The role of genetic factor in embryogenesis of fingerprints necessitates its correlation with disease conditions. [4]

The purpose of this review was to highlight information regarding embryogenesisand application of the fingerprints patterns in forensic and medical sciences. This review may help in revealing information that is useful to forensic community in terms of establishment of identity. It may also provide additional information on the potential of fingerprint features as diagnostic and screening tools in some diseases condition.

Materials and Methods

Pubmed, Science direct data bases were used while some information were collected by direct searching using Google search engine. Reference lists of identified articles were explored for additional articles. Certain keywords were used alone or in combination form in which the headings and subheading of the articles. In maintaining the focus of the review original research and reviewed articles were included. Case report and abstracts, editorial were excluded.

Embryology of Fingerprints

The epidermal ridge pattern depends upon the cornified layer of epidermis and dermal pattern. Proliferation of cells in the lower zone of epidermis resulted in projections in the dermis as regular spaced thickenings. The dermisalso projects upwards into the epidermal hollows, referred to as dermal papillae. This led to appearance of elevations on the surface of the skin known as epidermal ridges. [4, 5]

Establishment of Fingerprints

The crucial events for the establishment of the epidermal ridge pattern take place from the 10th to 16th weeks of development. At 10th week, embryonal volar skin consists of the layered epidermis on top of more amorphous fibrous dermis. At that moment the epidermis consists of three layers; periderm on the outside, the intermediate layer and the basal layer at the interface of the dermis. [4, 6-12]

During 11th week the basal layer of the epidermis consists of columnar cells whose axis is perpendicular to the skin surface. It’s observed that the basal layer becomes undulated, which quickly becomes prominent and form folds of the epidermis into dermis. These folds are called primary ridges which establish the future surface patterns which become well pronounced at the 16th week. Because fingerprints patterns are encoded at the interface between dermis, the pattern cannot be destroyed by superficial skin injuries. [4, 10, 13]

Spread of Epidermal Ridges

Primary ridge formation does not occur simultaneously on volar skin surface. The formation usually starts at a certain area in the middle of volar pad (which is called the ridge anlage) and along nail furrow, a little later along the interphalangeal flexion creases. The area of the ridge anlage usually coincides with the center of the whorl and loops if such pattern shows up. In this way, there are three ridge system on the fingertips (starting from the ridge anlage, the nail furrow and the flexion creases), which slowly spread over the fingertip. At the location where these ridge systems

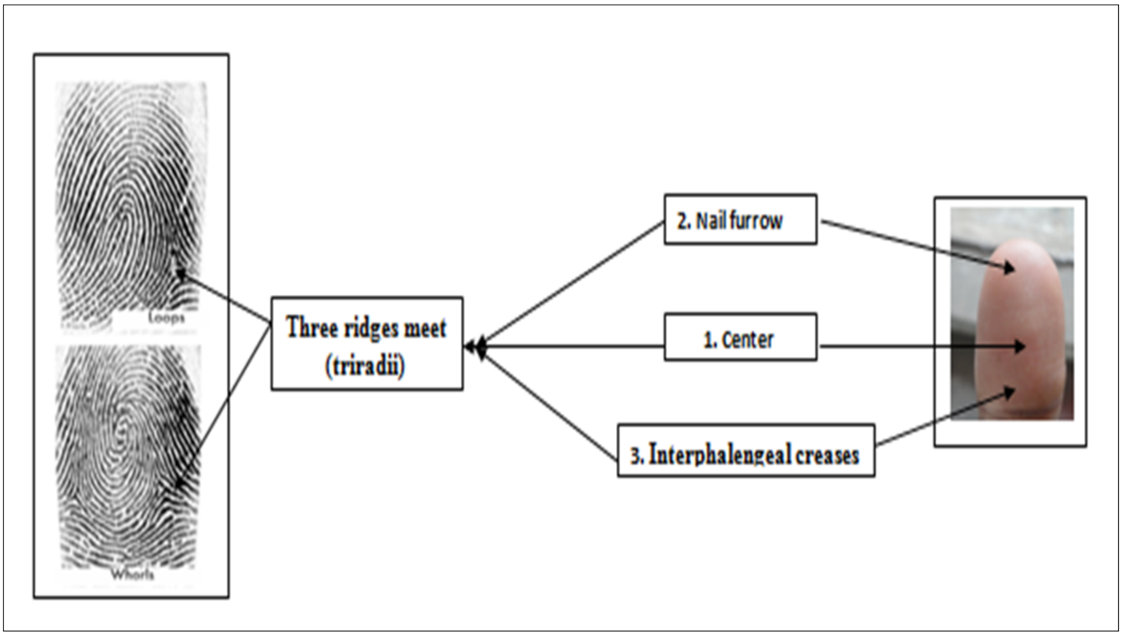

Figure 1: Stages in spread of epidermal ridges and formation of triradii

finally meet, triradii arises. [6, 7, 12, 13] This gives rises to complete fingerprints pattern (Figure 1).

It's likely from empirical evidence that the primary ridge system changes until the 16th week, when it becomes permanent. For example, it was observed that the number of minutiae significantly rises in that time. A possible reason for this observation could be a large growth rate of the finger compared with bridge of the ridges, which will lead to the insertion of new ridges as minutiae. [14]

Hypotheses of Ridge Formation

The different hypotheses were established which are key to the understanding of the embryology of the fingerprints. Although there is no general consensus on the mechanism for ridge formation to date, the following hypotheses in Table 1prove to be very important in the understanding of fingerprints formation.

Factors influencing fingerprints features

Several features are associated with fingerprints. The formation of fingerprints feature is influenced by several factors in utero. These factors can be summarized as follows Table 2: Factors influencing fingerprints features

Application of Fingerprints

Forensic Sciences

The main driving force of using fingerprints is the uniqueness and consistency once formed. [4, 26]In addition, non-volatile inorganic component of eccrine secretion from fingerprints has been shown to remain intact even when exposed to temperatures as high as 600°C. [27]The application of the new scanning Kelvin probe fingerprinting technique, which makes no physical contact with the fingerprint and does not require the use of developers, has the potential to allow fingerprints to be recorded whilst still leaving intact material that could subsequently be subjected to DNA analysis. [28, 29]The sole aim of using fingerprint is to establish identity. The identity can be informed of sex, ethnicity, and life style prediction.

Sex Determination

The fingerprints have features which can be used to determine the sex of individuals. Using

Table 1: Mechanism and limitation of the hypotheses of ridge formation

Hypotheses	Mechanism	Limitation
Folding and mechanical processes [6, 15, 16, 17, 18]	Folding process, which is induced by differential growth and the process, is parallel to the largest growth stress.	The sources of stress that produces the observed patterns not identify.
	Intense cell proliferation in the basal layer of the epidermis resulting in cylindrical cells, which evade the stress by folding toward the dermis.	
Nerve [19, 20, 21]	Fingertips are innervated by hexagonal pattern of axons whose wavelength roughly equals to the one of fingerprints.	A ridge direction and ridge formation has still been observed in experiments where innervations was prevented.
Fibroblast [22]	Fibroblast cell pattern are similar to fingerprints pattern, thus it formation is induced by pre pattern of the fibroblast in the dermis.	What induced the formation of the pre pattern of the fibroblast in the dermis not clear
Biochemical [23]	The repetition of the pattern was due to a specialized biochemical system (morphogens) allowing formation of the wrinkles in the fingerprints.	The exact influence of each biochemical and mechanical factors on the formation of surface pattern becomes an experimental challenge.

Table 2: Factors influencing fingerprints features

Factors	Definition	Features	Comments
Volar pads[24]	Temporary eminences of the skin surface that form during the 7th week of development	Pattern	· Highly rounds symmetrical pads whorls;
			· Less well developed asymmetric pad shows loops
			· Pad slanted to the right give rise to loop opening to the left and vice versa.
			· Small indistinct pads (flat pad) give rise to arches.
Boundaries[18]	Nail furrow, flexion creases and margin of the fingertips	Pattern	· Act as obstacles to expansion and greatest stress form perpendicular to these obstacles.
Markel cells[18]	Epiderrmal cell which are in con-tact with nerve endings	Minutiae	· The location of the Merkel cells determines minutiae
Genetic[25]	Gene mutation and protein ex-pression	Ridges	· Proper expression of SMARCAD1 may be im-portant to ridge formation, and the disruption of its expression causes adermatoglyphia.

fingerprint patterns, it was reported that females have more arches, and males have more whorls. Males' prints tend to have higher levels of urea than women's. [30] Males were also reported to have coarser ridges than females by approximately10%. [31] Females had a significantly higher ulnar ridge density in the right thumb among Hausa population of Kano state. [32]It was reported that females had higher ridge counts in all the ulnar, radial and proximal areas among Mataco-Mataguayo [33] Sudanese [34] and Argentinian [35] populations. On average females have finer ridge compared to their male counterparts.

Ethnic Differentiation

A population-wise comparison demonstrated that ridge densities recorded amongAfricans (Sudanese and Nigerians). [32, 34] were lower than those reported among Argentinians. [35] Spaniards [36] and central Indians. [37], using the same methodology. This may give insights into the possible occurrence of lower ridge counts among people of African descent. [32]. Confounding variables, such as age, need to be considered when making a comparison between sexes and the populations under study. This is because ridge density, which is permanent after formation, decreases with age and, at all ages, ridge density is higher on the distal (radial and ulnar) area, followed by the proximal sides. Females were found to have higher ridge density than males when older than 12 years, but not when younger in the Mataco-Mataguayo population. [33] This is consistent with changes in body composition and proportions, which differ among populations and depend more critically on sex at a specific age. [32]

Life Style Prediction

Gelatine based tape and high-tech chemical analysis under spectroscopic microscope reveals the chemical- and metabolic make-up found on a fingerprint. The study revealed that specific amino acids indicated whether the "suspect" was a vegetarian or meat-eater.[30] Spectroscopic microscope method based on the study of chemicals and metabolic featured with a fingerprint can also reveal the use of substances, including: cigarettes, drugs, grooming products etc. [30]

Risk of Diseases

The earliest scientist to explore the potential of fingerprints in clinical medicine was Cummins.[38] Fingerprints are used as a diagnostic tool in a number of diseases which have strong hereditary basis. [39, 40] Two different approaches are adopted a) Quantitative approach; this based on the fingerprints patterns, basically loops, arches and whorls. For example, there is decrease in frequency of ulnar loops and increase in arches in patients with cancer of the cervix. [41] b) Qualitative approach; this involves the ridge counts, total or absolute. [42, 43] (Schaumann and Alter, 1976; Chimne and Ksheersagar, 2012)for example in Klinefelter's syndrome a total reduction of finger ridge count was reported. [44] Whereas increase in total finger ridge count was noticed in patients with essential hypertension. [45]In general a remarkable improvement has been achieved in the concept of association of fingerprints and some individual disorders. [46, 47] However, it should be noted that the findings are population specific. A particular trait in a diseased population may be observed in a healthy population. For example, total ridge counts were prominently higher than the control group in both right and left hands of the female and male patients with multiple sclerosis (MS). [48]On the contrary, in another population ridge counts in the fingertips of patients with MS were lower than the control group. [49] In schizophrenia, these case subjects were found to have more number of arches and loops and less whorls[50]. In contrary, it was established that there was significant increase in whorls and decrease in loops in male schizophrenic patients. [51]

Conclusion

The crucial events for the establishment of the epidermal ridge patterns take place from the 10th to 16th weeks of development. These established the future surface patterns which become well pronounced at the 16th week. Primary ridge formation does not occur simultaneously on volar skin surface. The different hypotheses were established which are key to the understanding of the embryology of the fingerprints. Although no universal accepted mechanisms for ridge formation exist, both environmental and genetic factors have role to play in the formation of the fingerprints. The primary aim of using fingerprints is for personal identification these can be achieved through revealing sex, diet and lifestyle of an individual. Fingerprints can also be used to establish risk of disease conditions. However, this potential is population specific and should be interpreted differently across different population.

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