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REVIEW ARTICLE

Dermatoglyphics and Type 2 Diabetes Mellitus: Review

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Abstract

Study of epidermal ridges on the skin covers the palmar and plantar surface of hands and soles, and is known as Dermatoglyphics (also known as fingerprints). Dermatoglyphics patterns are genetically determined and are affected by environmental factors in the uterus. After their formation, they remain stable, unchanged, and are not affected by postnatal environment or age. Dermatoglyphics can serve as a reliable marker of individual identification, as they can be a morphological trait, and a mirror to explain genetic and environmental factors in the first trimester of pregnancy. Diabetes is a chronic disease with serious complications if not managed well. In fact, 90% of diabetics are type 2 diabetes mellitus, multifactorial metabolic syndrome. T2DM will not be diagnosed until the long-term complications. Early diagnosis and treatment are very important to prevent long-term complications of the disease (such as retinopathy, neuropathy, nephropathy), and predicting people with high risk of T2DM can be useful in preventing disease and complications. In this review, we will discuss dermatoglyphics, and the main results of researchers who studied Dermatoglyphics for T2DM patients.

Keywords: *Dermatoglyphics, T2DM, Arch, Loop, Whorl, Ridge count.*

Introduction

Dermatoglyphics (Fingerprints) refers to the study of all features of ridged skin [1]. Cummins and Midlo first formulated this term in 1943, derived from the Greek words "dermato" which means skin and "glyphics" means carvings [2]. The ridged skin (also known as the friction ridges skin) is located on the digit and palmar surface of the hands (known as fingerprints and palm prints) and on the plantar surface and the toe of the feet. It is believed that the mechanical function of these ridges conveys a firmer grip and prevents slippage [3], and is also believed to enhance the sense of touch [4].

Diabetes is a serious and chronic disease that occurs, either when the pancreas cannot produce enough insulin, or when the body cannot use insulin effectively [5]. It is characterized by high levels of glucose in the blood, which may lead to progressive damage in most tissues and organs of the body such as heart, blood vessels, eyes, kidneys, skin, and nerves.

According to the international Diabetes Federation, in 2017 there were 425 million people with diabetes, and there are expected to be more than 629 million patients by 2045 [6]. There are two types of diabetes mellitus; type 1 and type 2 (formerly known as insulin and non-insulin diabetes mellitus). The most common type of diabetes is type 2 diabetes (T2DM) (about 90% of diabetics). It was previously called non-insulin-dependent or adult-onset diabetes. Symptoms of T2DM are often less obvious or absent. Therefore, the disease may not be diagnosed for several years, until the complications have already appeared [6].

Early diagnosis and treatment are very important to prevent long-term complications of the disease (eg retinopathy, neuropathy, and nephropathy). The prediction of people with high risk of developing T2DM is useful not only for disease prevention, but also to prevent the disease complications.

Historical Review and Pioneers of Fingerprints and Dermatoglyphics

Ancient civilizations such as Mesopotamia, Indus, Chinese and Egyptians were all familiar with the uniqueness of individual fingerprints. Fingerprints were used as a sort of stamp or brand mark on pottery or as seals to give authenticity to important documents. Clay tablets containing fingerprints belonging to ancient Assyria were found, and are now found in the British Museum [3]. In 1684, one of the first fingerprint publications was presented by Dr. Nehemia Gro, a Fellow of the College of Physicians and Surgeons of the Royal Society of England.

In 1686 another scientific paper was published by Marcelo Malphighi, professor of anatomy at the University of Bologna, Italy. Later one of the skin layers of skin was named by his name "the Malphighian layer" for his magnificent work in this field [7]. In 1823, Dr. Johannes Evangelist Burkinge, Professor of Physiology at the University of Breslau, classified fingerprint patterns into nine standard types. In 1858, Sir William Herschel, the Hooghly Collector distract in Bangal under the British government, recommended using fingerprints on official contracts instead of signing in order to avoid any disguises or deceptions in the future. Dr. Henry Faulds was a Scottish Physician who spent many years in Japan at Tsukiji Hospital in Tokyo, in 1880 based on his experiences and research, suggested using fingerprints accidentally left by a criminal at the crime scene to make a positive identification of the real criminal. After that, Dr. Henry wrote a textbook on fingerprint procedures [7].

In 1892, Sir Francis Galton, a British anthropologist, and based on the material collected by Sir William Herschel, published his famous book "Fingerprints", which was the first systematic scientific study of fingerprints, established the fundamental principles of fingerprints (the permanents of the ridged skin, the uniqueness of individuals fingerprint and the classification of fingerprints patterns). He also discussed the anatomy of ridged skin and classified the fingerprint patterns into three main groups (Arches, Loops, Whorls), in addition he described and classified the characteristics of the ridges (which called Galton details or Minutia). In 1891, and according to the Galton book, Dr. Juan Vucetich, an Argentinian criminologist, developed a classification system for fingerprints. Dr. Juan classification system has been refined over time and is still used in most Latin American countries. Furthermore, Sir Edward Richard Henry, an English police officer stationed in Bangal, India, based on the work of Galton and with the assistance of two Bengali officers Khan Bahadur Azizul Haque and Rai Bahadur Hemachandra Bose of the Anthropometric Office, developed a classification and storage system. In Henry classification fingerprint system, the patterns were modified into four main groups (Arch, Loop, Whorl, Composites), and each group was divided into subgroups.

In 1900, Sir E R Henry published a textbook (Classification and Uses of Fingerprints), and later the Henry classification system transferred an anthropometric system from Bertilon, which until then had been in use [7]. Harris Hawthorne Wilder, an American professor of zoology at Smith College, Northampton, Massachusetts, USA, was interested in zoology, human anatomy and forensic science. He introduced Dermatoglyphics and the developments in this field to the American public [8].In 1926, Dr. Harold Cummins (a Professor of Anatomy at Tulane University School of Medicine, New Orleans, Louisiana, USA) named this branch of science “Dermatoglyphics”. In 1943, Professor Cummins with the assistance of his colleague Charles Medlow, presented his book "Fingerprints, Palms and Soles Introduction to Dermatoglyphics" commonly referred to as Cummins and Midllo [2]. Professor Cummins found that Mongolian patients (Down syndrome) showed distinctive features in the skin and fingers.

He reported that dermatoglyphics were valuable in the diagnosis of Mongolian. His findings were the foundation of clinical dermatoglyphics science [9]. Since then, many researchers have been interested in analyzing finger and palmar prints, and their associations with various syndromes such as Professor Lionel Sharples Penrose and Dr. Sarah B. Holt, who were interested in the inheritance of the dermatoglyphics [4]. Penrose and Holt were published many papers that contributed to the progress of Dermatoglyphics and genetics of dermal ridges [10-14]. In fact, a positive correlation between medical disorders and dermatoglyphics anomalies has been established by many researchers, including disorders caused by autosomal aberration such as Down syndrome (Mongolian), or because of sex chromosomal aberration, and other Inherited disorders [3, 4].

Dermatoglyphic Formation

Dermal ridges differentiation occurs at an early stage of fetal development starting from the 3rd month of the intrauterine life and lasts until the 4th month. Once formed, they remain permanent and never change during the life span except in the dimensions that proportional to the growth factor. The ridges configurations resulting from genetic factors are modified by the influence of environmental factors and growth factors during the formation period [3, 15].

One of the important characteristics of the dermal ridges is that they reflect growth troubles that occur before and during their development [1], occurring during early fetal life, along with major tissue differentiation. Therefore, any abnormal genetic expression or environmental factors that may affect subsequent life may also affect the fingers and palms ridged skin.

Digital Dermatoglyphics

On the digital distal phalange, the dermal ridges set as patterns, these patterns can be classified primarily into three types according to Galton, arch, loop and whorl. Each pattern located in the middle of the finger ball. Loops and Whorls patterns contain an important landmark called Triradii. A triradius is located at the meeting point of the three opposing ridge systems.

Triradii is a pattern area, also called delta, can be determined with the help of the triradii point, which is also an important landmark in the ridge counting [2]. The eminent ridges from the triraduis and enclose to the pattern area are called Radiant [16].

The main patterns of the papillary ridges in the fingerprint area are:

Arch

Arch is the simplest pattern in which the ridges flow directly from side to side, and may be with a slight elevation in the middle (Figure 1), it can be sub divided into plane arch and tented arch [17]. Plane arch or simple arch composed of ridges flow directly from one end to the other end without any recurving. Tented arch consists of ridges that converge at a point so that its soft sweep is interrupted [15]. Arch pattern occurs in 5% of fingerprints [3].

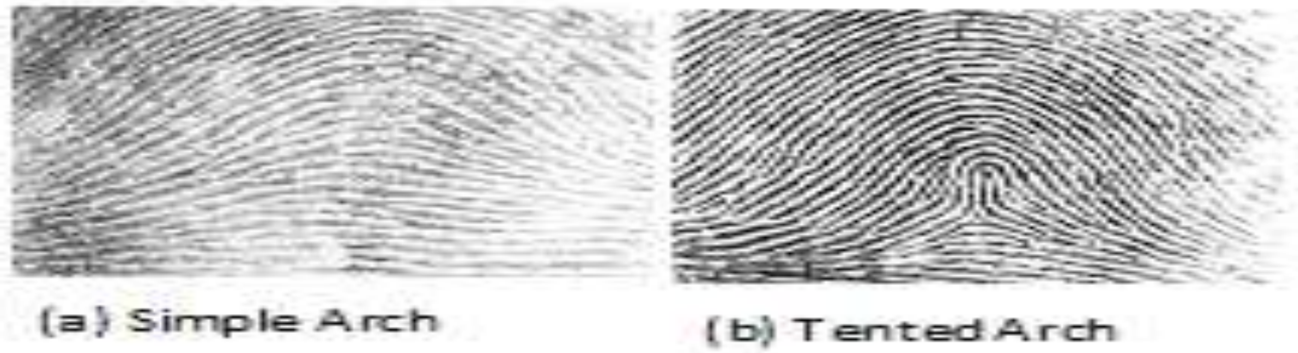

Figure 1: Arch Pattern (a) Simple Arch Pattern (b) Tented Arch Pattern

Loop

Loop consists of one triradii, the ridges in this pattern enter from one side and return to exit the pattern area from the same side (Figure 2). It must contain at least one recurving ridge between the core point of pattern and the triradii point. If there is no ridges recurve between the core and triradii, the pattern will classified as Tented Arch (Figure 1b). The loop pattern can be subdivided into Ulnar Loop and Radial Loop. When the ridges are entering and exiting from the ulnar side it will called ulnar loop, and if the ridges enter and exit from the radial side it would be called a Radial loop [18]. To determine whether the loop is ulnar or redial, it depends on which hand is that finger, ulnar loop on the right hand similar to a redial loop on the left hand. Loops occur at about 60-70% of fingerprints [3]. Therefore, their shape and size may vary greatly, and they may be a regular ring or double ring. Sometimes, transitional loops can be found that look alike whorls or complex patterns [16].

Figure 2: Loop Pattern
(a) Radial Loop when found in right hand (Ulnar if in left hand)
(b) Ulnar Loop when found in right hand (Radial if in left hand)

Whorl

Whorl pattern is the most advanced pattern (Figure 3), where any pattern that involve two or more triradii's is considered as whorl. The whorls pattern occurs at about 25-35% on the fingerprint, and can be divided into four types as follows [15]:

- Plain whorls: consist of one or more ridges that form a complete circle with two deltas.
- Central pocket loop whorls: consist of at least one re-curving ridge or obstruction in the right angles of the flow line, with two deltas. In this type when the imaginary line is drawn, no re-curving ridge is cut or touched within the pattern area.
- Double loop whorls: consist of two separate and distinct loop formations with two separate and distinct shoulders for each core, in addition to two deltas and one or more ridges that form a complete circuit.
- Accidental whorl: is a pattern that contains some requirements for two or more different types, or a pattern that does not comply with any of the definitions.

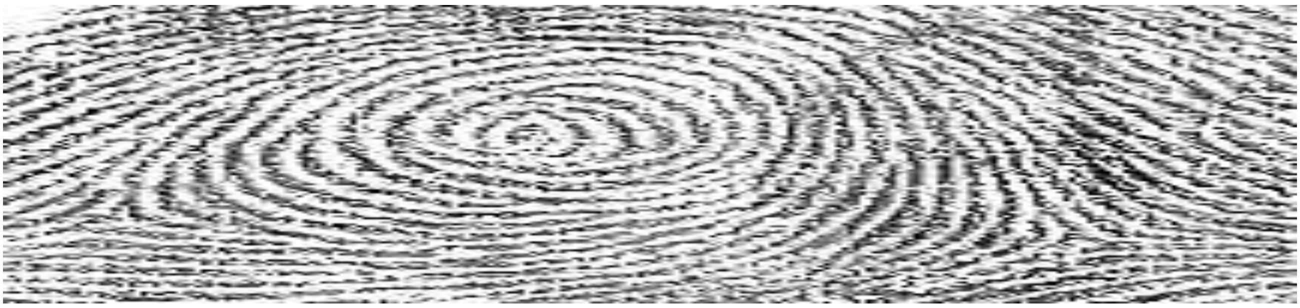

Figure 3: Whorl Pattern

Ridge Count

Ridge count is used to indicate the size of pattern. The counting is done along the straight line that connects the triradial point with the point of pattern core in loops and Whorls. Both ridges containing the core point and triradial point are excluded from the count. [19]. In the ridge counting, the Arch pattern usually has a zero ridge count because it is without a triradii point. Loops usually contain only one ridge count because it contains only one triradii point.

Whorls contain tow triradii points, one near to the ulnar side and the other is near to the radial side, so in the Whorl pattern there will be tow ridge counts. In a double loop whorl, the counting is done from the triradii to the core that is nearer the triradii [20]. Fingerprints can be analyzed qualitatively and quantitatively. Qualitative analysis including the fingerprints patterns and their distribution and frequency on the different fingers .Quantitative analysis include: the ridge count on each fingerprint pattern, the sum of ridge count of all ten fingers is called (Total Fingers Ridge Counts TFRC). In this count, only one count is taken to each finger, in the Whorls pattern the higher ridge count is taken, TFRC represent the pattern size [20]. Absolute Fingers Ridge Count (AFRC) is the total of the ridge count of all fingers. AFRC reflects intensity and size of the pattern [20]. Next to TFRC and AFRC there are other fingerprint indicators, these include:

Pattern intensity index (PII): [(2 ×%whorl +% loop) /10] [15]

arch/whorl index of Dankmeijer"s; (% arches÷% whorl) × 100 [21]

whorl/loop index of Furuhata"s; (% whorl÷ % of loop) × 100 [17]

Palmar Dermatoglyphics

The palm has been divided into several anatomically designed areas includes thenar, four inter-digital zones (1st, 2nd, 3rd, 4th), and the hypothenar area (Figure 4). Thenar and first inter-digital area are closely related anatomically and are considered as one area [16]. In the distal part of the palm, there are four triradii (one proximal to each finger except the thumb), they are named (a, b, c and d) from index to little finger respectively [17]. Each of these triradiis consists of two distal radiants (digital radiants) and a proximal radiant.

The proximal radiant is directed towards the interior palm zone. These proximal radiants are known as the palmar main lines and are named corresponding to the digital triradii (A, B, C and D) and distinguished by using capital letters [2]. There are also axial triradii called (t, t', t'') depending on their position [18]. There are also the flexion creases in the palm zone. Flexion creases are not components of dermatoglyphics but represent sites of attachment of the skin to underlying structures [4]. The main flexion creases are: (1) the distal transverse crease (called the line of Heart), (2) the proximal transverse crease (called the line of Head), and (3) the radial longitudinal crease (called the line of Life). These creases can aid in formulate the formula of the palm main lines [2].The qualitative analysis of palmar dermatoglyphics includes the presence of patterns in the palm areas (inter digital patterns) and there frequencies, the presence of more than one axial triradius, and palmar main lines tracing.

The palmar quantitative analysis usually involves the ridge count between the distal triradii such as (a triradii and b triradii). In addition, the measurement of the palmar angles such as the (palmar atd angle) by drawing a line connecting triradius (a) with the axial triradius (t), and a line connecting axial triradius (t) with triradius (d), and measure the angle between the two lines (atd angle), Figure 4.

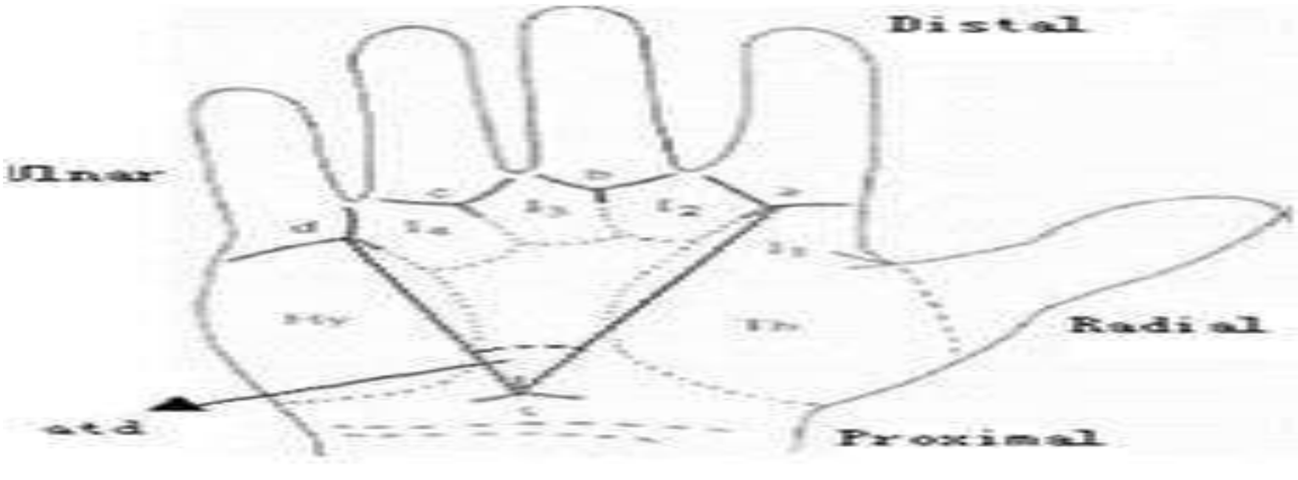

Figure 4: Main Palmar Dermatoglyphics

Dermatoglyphics and Diabetes Mellitus

Study of the dermatoglyphics features can be a useful tool for diagnosing many diseases; if caused by chromosomal abnormalities, which are often accompanied by pattern distortion; and in other diseases, whether hereditary, non-hereditary or both.

Many researchers studied dermatoglyphics and their anomalies presence with different diseases. In this review, we will include the research articles that studied dermatoglyphics in Diabetes Mellitus (DM) patients in different populations, specifically Type 2 Diabetes Mellitus (T2DM). Excluded criteria include a research article that contains mixed types of DM or any type other than T2DM. The English-language articles are included only. Table 1 contains the articles listed in this review, and presented important statistical results.

Digital Dermatoglyphics

Fingerprints Patterns

It has been reported by Sachdev [25] that Arch fingertip pattern is significantly higher in T2DM group, for both sexes, compared to control group. While, it was found by Burute and Padmini *et al.* [21, 24] that Arch fingertip pattern is significantly higher only in females T2DM patients than control.

Table 1: Important statistical results provided by all the studies included in this review

	Country	Population	Year	T2DM patients group			Control group			Reference
				Total	Male	Female	Total	Male	Female	
1	Romania	Moldova	2006	190	60	130	200	100	100	22
2	India	Karnataka	2006	112	63	49	142	65	77	23
3	India	Pradesh	2011	140	70	70	140	70	70	24
4	India	Rajasthan	2012	100	65	35	150	75	75	25
5	India	Maharashtra	2013	100	50	50	100	50	50	26
6	India	MadhyaPradesh	2013	100	50	50	100	50	50	27
7	India	Maharashtra	2013	101	51	50	100	50	50	21
8	India	Gujarat	2014	100	50	50	100	50	50	28
9	India	Udaipur	2014	100	50	50	100	50	50	20
10	India	Puducherry	2014	74	37	37	74	37	37	29
11	India	Hyderabad	2015	100	50	50	100	50	50	30
12	India	Kerala	2015	56	28	28	56	28	28	31
13	India	Maharashtra	2015	50			50			32
14	India	West Bangal	2016	30		30	60		60	33
15	India	West Bangal	2016	30		30	60		60	34
16	India	Ganjam	2016	100	50	50	100	50	50	35
17	India	Srinagar	2018	72	35	37	100	52	48	36
18	India	Chennai	2018	200	100	100	200	100	100	37
19	India	Karnataka	2018	44	29	15	45	25	20	38
20	India	Bangalore	2019	150	75	75	150	75	75	39

In addition, it was found that Loop fingertip pattern is significantly higher frequency in T2DM groups, for both sexes, compared to control [25]. While it was observed significantly lower frequency in T2DM group, for both sexes, in Pathan *et al.* study [26]. Another study conducted by sharmila et al. showed that loop pattern was most dominant fingerprint pattern in both sexes and slightly more in female diabetic. Further analysis showed that higher frequency of ulnar-loop pattern in the T2DM patients group as compared with control group [37].

Also, ulnar loop was found with higher levels in T2DM patients in comparison with the control group [38]. Furthermore, many studies have indicated that Whorl fingertip pattern was significantly higher frequency in T2DM groups, in both sexes as compared with the control group [26, 29, 30, 39]. The same observation was found but only in T2DM male patients in Ojha *et al.* study [20]. On the other hand, other studies have shown that whorl pattern is much lower in T2DM patients for both sexes when compared to the control group [21, 25, 38].

Total Finger Ridge Count (TFRC) and Absolute Finger Ridge Count (AFRC)

Several studies have been revealed that FRC is significantly increased in T2DM patients, and for both sexes [20, 24, 35]. In another study conducted by Srivatsava *et al.*, TFRC was found to be higher in both hands of male and female right hand only [39].

While Brutue *et al.* showed that TFRC significantly decreased only in the female T2DM patient group [21]. On the other hand, AFRC was found to be significantly increased in both sexes of T2DM patients [24, 39]. While was found to be significantly increased only in female T2DM patient group [20]. Brutue et al. reported that AFRC was decreased significantly only in female diabetic group [21].

Palmar Dermatoglyphics

Palmar Angles

All studies that analyzed the palmar atd angle are almost consistent in their observations that the palmar atd angle increases in the diabetic group when compared with the control. Several studies noted a significant increase in the palmar atd angle for both hands of patients (male and female) with T2DM compared to the control group [20, 23, 24, 27, 32, 38]. Similar results were observed in a study by Ghosh *et al.*, which analyzed atd angle in female with diabetes only [33]. In addition, another study conducted by Trivedi *et al.*, showed that the atd angle was much higher in the right hand of males only [28].

A previous study conducted by Ojha et al., which analyzed of other palm angles such as dat palm angle, showed an increase in dat palm angle for T2DM group [20]. Whereas observed in Mohan *et al.*, that the palm dat angle decreased significantly in the right hand only in the T2DM group [31].

Another study conducted by Nazir *et al.*, revaeled that dat angle decreased significantly in both hands of T2DM patients group [36]. Furthermore, the palmar adt angle was found significantly reduced in both hands of the T2DM group of both sexes in comparison with control group [20, 27, 36]. Ghosh *et al.*, analyzed other palmar angles in females only. The palmar btd angle was observed to be significantly increased in both diabetic female hands, and ctd angle observed to be significantly decreased in the female diabetic group in comparison to the female control [33].

Palmar a-b Ridge Counts

A previous study conducted by Tarca *et al.*, observed that a-b ridge count was significantly decreased in T2DM female left hand as compared to female control group [22]. While another study conducted by Ghosh *et al.*, showed that a-b ridge count was significantly decreased in both hands of female T2DM patients group [33]. Pathan et al., study observed that a-b ridge count was also significantly decreased in T2DM patients group for both male and female [26].

Palmar Axial triradius (t, t', t'')

Several studies have reported the presence of an extra palmar axial triradii is observed in high frequency [20, 22, 23, 33]. Moreover, Tarca study observed that the absence of the palmar axial triradii was also observed in T2DM patients group in comparison the control group [22].

Palmar Patterns

The statistically significant findings were as follows: Tarca observed the presence of ulnar loop pattern in the palmar hypothenar zone on both hands of both sexes of the patients group, and the presence of radial arch pattern in the palmar hypothenar zone on the right hand of both sexes patients group [22]. In addition, Dastidar *et al.*, observed the presence of higher frequency of 4th inter digital patterns in T2DM patients group in both hands [34].

Main C-line Formula

The palmar main lines that can be traced; can be classified into: Radial, Ulnar, Proximal, and absent. The significant observation on the Main C-line pattern is as follows: the absence of main C-line was found to be significantly higher frequency on diabetic patient's hands for both sexes [22, 26, 34]. While another study conducted by Ojha et al., was observed to be significantly lower frequency in T2DM patients compared with control group [20]. The Proximal C-line was observed to be significantly decreased frequency in T2DM group according to the observations of Pathan *et al.*; and Dastidar et al. studies [26, 34]. Furthermore, the Radial C-line was found to be significantly higher frequency in T2DM patients group compared with the control group according to Ojha *et al.*; and Dastidar et al. studies [20, 34].

Meta-analysis and Cohort Studies

A meta-analysis study conducted by Yohannes [40] concluded that dermatoglyphics in the T2DM group showed a significant reduction in Loop pattern along with an increase in non-loop patterns (Arch and Whorl), with increased atd angle and reduced AFRC, these findings support that there is a distortion in Early pregnancy among diabetics. In the Dutch Hunger Winter Families Cohort study by Kahn *et al.*, [41] a Dermatoglyphics marker (MD15) (Mean Ridge count of 1st digit – Mean Ridge count of 5th digit) was used, and correlated with late onset diabetes (T2DM). It was found that risk factor of developing diabetes increased with the increase of MD15 value.

Conclusion

Dermatoglyphics reflect as a marker, the effect of genetic factors and non-genetic factors in the first trimester of intrauterine life, in which any abnormal expression on the main tissues may be reflected in dermatoglyphics features. Dermatoglyphics features are easily accessible and cost-effective, and can be categorized and analyzed qualitatively and quantitatively. When dealing with any medical disorder or clinical conditions, the control group should be carefully collected, along with gender and race differences in dermatoglyphics. In this review article, it can be concluded that dermatoglyphics investigations may be used as an additional screening tool to identify early risk factors that may help prevent additional complications of type 2diabetes.

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