University of Shendi

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COMPARISON BETWWEN FINGERPRINT PATTERNS OF THE SIBLINGS AND THEIR PARENTS.

A thesis submitted in full fulfillment required for Ph.D. in human anatomy

BY

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آيات

قال تعالى:

بسم الله الرحمن الرحيم

سَنُرِيهِمْ آيَاتِنَا فِي الْآفَاقِ وَفِي أَنْفُسِهِمْ حَتَّىٰ يَتَبَيَّنَ لَهُمْ أَنَّهُ الْحَقُّ أَوَلَمْ يَكْفِ بِرَبِّكَ أَنَّهُ عَلَىٰ كُلِّ شَيْءٍ شَهِيدٌ﴿ **سورة فصلت٥٣** ﴾

صدق الله العظيم

Dedication

To my parents, and daughter,

To my brothers and sisters,

To all whom I love and respect.

Acknowledgements

First of all I thank Allah for giving me the strength and patience to do this work. I would like to express my deepest gratitude to my supervisor prof. Ahmed Mohamed Ahmed Ibrahim for always being ready to help me and knowing what to do whenever anything went wrong. I wish also to express my deep gratitude to D. Yasser Siddige for helping me and keeping me on task. My deep thanks to the Major Mohamed Abd Almuez for taking time out of his busy day to let me come down and get a better understanding of fingerprinting technique. My special thanks owed to all families included in this work. Lastly, but not least I would like to thank all my friends specially Mr. Ahmed Hussain, Mr. Adam Dawria, and Mr. Habib for being ready to help in statistical analysis even when they have other things to do.

مستخلص الدراسة

أجريت هذه الدراسة ألوصفية لاكتشاف العلاقة بين أنماط بصمات اصابع الأبناء وأنماط بصمات أبائهم. لإجراء هذه الدراسة، تم جمع ومقارنة بصمات مائة أسرة تتكون كل منها من الأبوين وأثنين من أبنائهم أو بناتهم، أثناء الفترة من مايو 2015 إلى يناير 2018.

طبقا لنتائج الدراسة، وجدنا أن أكثر الأنماط تكرارا في كل ال 4000 إصبع هو المنحدر والذي يمثل63.3%، يليه النمط الدائري بنسبة 31.82%، واقل الأنماط تكرارا هو المقوس حيث يمثل4.77%.

ويظهر التحليل الإحصائي وجود علاقة ارتباط معنوية بين نمط بصمة الأشقاء أكثر من العلاقة بين الأبناء ووالديهم، وعلاوة على ذلك فإن اليد اليمنى واليسرى لهما نفس نمط بصمات الأصابع.

وخلصنا إلى أن نمط البصمة الأكثر شيوعا هو المنحدر يليه الدائري ثم المقوس. كما يتشارك الاخوة الحمض النووي، نجد لديهم تشابه أعلى في نمط بصمات الأصابع مقارنة مع الأشخاص غير ذوي الصلة.

والنتيجة التي تم الحصول عليها قد تساعد الشرطة في التحقيق الجنائي، وفي الطب الشرعي.

Abstract

This is a comparative descriptive study aimed to find out the relationship between siblings fingerprints patterns and that of their parents. To do this study, all ten fingerprints were examined from hundred families, consisting of two biological parents and two of their offspring, of Sudanese community. They formerly live in the town of Jabal Awlya, 45 km to the south of Khartoum. The study was done during the period from May 2015 to January 2018.

According to obtained results, the most frequent fingerprint pattern in all 4000 fingers examined is loop pattern, which represents 63.3%, followed by whorl pattern, which represents 31.82% and least frequent pattern is arch (4.77%).

The statistical analysis shows significant correlation between siblings fingerprint pattern more than the correlation between sibling and their parents, furthermore the right and left hands had same fingerprint pattern.

We concluded that the most common fingerprint pattern is the loop followed by whorl then arch. As sibling share DNA, they has higher similarity in fingerprint pattern comparing to non-related people.

The obtained results may help police in criminal investigation, and in forensic as well as solving medico-legal problems.

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List of abbreviations:

Abbreviation	**Explanations**
AFIS	Automated fingerprint Identification Systems
AFRS	Automatic Fingerprint Recognition System
FBI	Federal Bureau of Investigation
LI	Left Index finger
LL	Left Little Finger
LM	Left Middle finger
LR	Left Ring finger
LT	Left Thumb finger
RI	Right Index finger
RL	Right Little Finger
RM	Right Middle finger
RR	Right Ring finger
RT	Right Thumb finger
Sib1	Sibling group 1
Sib2	Sibling group 2
UL	Ulnar Loop
W	Whorl

1.1. Introduction:

Biometric systems based on the fingerprint recognition are considered one of the most important identification techniques. It is a successful way to determine the identity of the person that cannot be faked or stolen easily. Recently, we see increasing the demand of strict security systems to protect places and people and information from any unwanted interventions of unauthorized.(Al-ani and Al-Aloosi 2013)

Fingerprints, which have been used for about 100 years, are the oldest biometric signs of identity. The foundations of modern fingerprint identification were established by the studies of Sir F. Galton (Galton 1892) and E. R. Henry (Henry 1905). Since then, fingerprints have been used for identification in many social conditions such as access control, crime investigation, personal trust etc., since they will remain almost constant during people's lifetime (Jain, Halici et al. 1999). Nowadays, the Automatic Fingerprint Identification System (AFIS) and the Automatic Fingerprint Recognition System (AFRS) (Jain, Halici et al. 1999) are very popular due to fingerprints' lower changeability and easier accessibility than other methods such as signature and hand geometry (Zhang and Yan 2004).

The use of fingerprints for identification is based on the immutability and the individuality of fingerprints. Immutability refers to the permanent and unchanging character of the pattern on each finger, from before birth until decomposition after death. Individuality refers to the uniqueness of ridge details across individuals. No two persons, even identical twins, have been found to have identical fingerprints, despite elements of similarity. (Hrechak and McHugh 1990).

Fingerprints have two levels of structure: the Henry (1900) fingerprint pattern (with ridge count) and the Galton (1892) characteristics (Figure 1.1). The Henry Classification is the standard qualitative scheme for characterizing the global structure of ridge patterns and has traditionally been used to partition fingerprint databases. (Hrechak and McHugh 1990)

At approximately 10 weeks of embryonic development, the epidermal ridges on the palms and fingertips begin to develop precise, minute patterns, which are fully formed at approximately 25 weeks (Penrose and Ohara 1973). Each individual exhibits unique finger and palm print configurations determined by both the genetic profile of their parents and the intrauterine environment (Babler 1987) The similarity in the types of fingerprint patterns found on homologous fingers of the right and left hands is referred to as fingerprint pattern concordance. Fingerprint pattern concordance is an example of a fluctuating asymmetry, representing environmental disturbance (Palmer and Strobeck 1986).

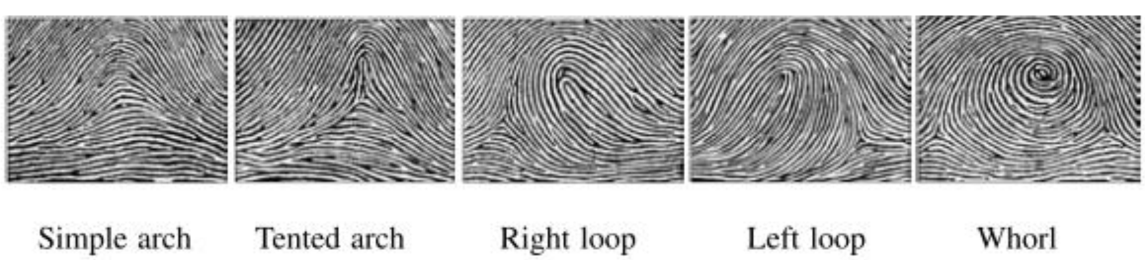

Figure 1.1: Fingerprint pattern (arch, loop, and Whorl)

(Champod, Lennard et al. 2017)

1.2. Objectives:

1.2.1. General objective:

To study the general fingerprints patterns in Sudan.

1.2.2. Special objectives:

- To correlate between fingerprints patterns of the siblings and their parents among Sudanese population.
- To detect the most common fingerprints patterns in the study samples.
- To find out if the general fingerprint patterns of siblings match each other.
- To find out if the general fingerprint patterns of siblings match their father.
- To find out if the general fingerprint patterns of siblings match their mother.

1.2.3 Hypotheses:

- Loop is the dominant fingerprint pattern.
- There is similarity between fingerprint patterns of sibling.
- Fingerprint pattern run in family

1.3. Rational

Society has come a long way with the discovery of fingerprinting. Fingerprints offer a reliable means of personal identification. That is the essential explanation for fingerprints having replaced other methods of establishing the identities of persons unwilling to admit previous arrests. The science of fingerprint identification stands out among all other forensic sciences for many reasons as it easiest and unchangeable.

There are a few studies done on fingerprint, and a poor literature concern about it. Although there was several studies around world concentrating on similarity of fingerprint pattern in families but there was no study done in Sudan.

2. Literature Review

2.1 Hand and Finger Geometry Identification System:

Hand and finger geometry-base verification and recognition is an important branch of biometrics to automatically verify and recognize individuals based on the distinguishing hand geometric characteristics. Hand and finger geometry recognition technique exploits a number of characteristics from the human hand such as finger length, finger width, finger area, finger thickness, palm width and curvature of the fingers at certain points to make personal verification and recognition. (Zhang, Lu et al. 2018).

Hand and finger geometry recognition technique obsesses dramatical merits. For example, hand-based system just utilizes simple imaging requirement by virtue of extracting features from low-resolution hand images. What's more, hand-based system is competent with the capability of operating and unaffected under turbulent and hash environmental conditions such as dry weather, or individual anomalies such as dirt on the hand, dry skin. These external factors do not appear to have any negative effects on the verification and recognition accuracy of hand and finger geometry technique. Furthermore, the low data-storage requirement is additional superiority.(Zhang, Lu et al. 2018).

The biometric system based on hand and finger geometry has been used in physical access control in commercial and residential applications, in time and attendance systems. Additionally, hand and finger geometry technique can be effectively implemented and inexpensive. Moreover, acquisition and authentication system are efficiently obtained.(Zhang, Lu et al. 2018)

2.2. Fingerprints:

Fingerprint analysis, also known as dactylography, is the science of using fingerprints to identify a person. Fingerprints are the most commonly used biometric and have been used for identification since the 1890's. In 1901, Sir Edward Henry introduced the Henry Classification System for fingerprints, which is widely recognized, even today, in Anglophone countries. In South American countries, a system devised by Dr. Juan Vucetich in 1892 is widely used. These manual classification systems are, however, being replaced by other techniques, which are more suitable for large scale electronic storage and analysis. Fingerprint identification is well established and a mature science. It has also been extensively tested in various legal systems and is accepted as an international standard for identification. Although law enforcement agencies are principal users of fingerprints, various electronic readers are now commonly available and are used for authentication purposes, mainly in access control applications (Roberts 2006).

2.2.1. History of Fingerprints:

Earthenware estimated to be 6000 years old was discovered at an archaeological site in northwest China and found to bear clearly discernible friction ridge impressions. These prints are considered the oldest friction ridge skin impressions found to date. The Chinese were the first culture known to have used friction ridge impressions as a means of identification. The earliest example comes from a Chinese document entitled "The Volume of Crime Scene Investigation—Burglary", from the Qin Dynasty (221 to 206 B.C.). The document contains a description of how handprints were used as a type of evidence (Xiang-Xin and Chun-Ge, 1988, p 283).(Holder, Robinson et al. 2011)

The first detailed description of the anatomical formation of fingerprints was made by Mayer in 1788 (Moenssens, 1971) in which a number of fingerprint ridge characteristics were identified and characterized. Starting in 1809, Thomas Bewick started using fingerprint as his trademark, one of the most important milestones in the history of fingerprints (Moenssens, 1971).

Purkinje, in 1823, proposed the first fingerprint classification scheme, which classified fingerprints into nine categories according to the ridge configurations (Moenssens, 1971).

It was not until the late sixteenth century that the modern scientific fingerprint technique was first initiated; Galton (1892); Lee and Gaensslen (2001)). In 1864, the English plant morphologist, Nehemiah Grew, published the first scientific paper reporting his systematic study on the ridge, furrow, and pore structure in fingerprints (Lee and Gaensslen, 2001).

Henry Fauld, in 1880, first scientifically suggested the individuality of fingerprints based on empirical observations. At the same time, Herschel asserted that he had practiced fingerprint recognition for about 20 years (Lee and Gaensslen (2001); Moenssens (1971)). These findings established the foundation of modern fingerprint recognition.

In the late nineteenth century, Sir Francis Galton conducted an extensive study on fingerprints. He introduced the minutiae features for comparing fingerprints in 1888. (Galton 1892).

An important advance in fingerprint recognition was made in 1899 by Edward Henry, who (actually his two assistants from India) established the well-known “Henry system” of fingerprint classification (Lee and Gaensslen, 2001).

By the early twentieth century, the formation of fingerprints was well understood.

The biological principles of fingerprints are summarized below:

1. Individual epidermal ridges and furrows have different characteristics for different fingerprints.
2. The configuration types are individually variable, but they vary within limits that allow for a systematic classification.
3. The configurations and minute details of individual ridges and furrows are permanent and unchanging. (Moenssens, 1971).

The first principle constitutes the foundation of fingerprint recognition and the second principle constitutes the foundation of fingerprint classification.

In the early twentieth century, fingerprint recognition was formally accepted as a valid personal identification method and became a standard routine in forensics (Lee and Gaensslen, 2001).

Fingerprint identification agencies were set up worldwide and criminal fingerprint databases were established (Lee and Gaensslen, 2001). Various fingerprint recognition techniques, including latent fingerprint acquisition, fingerprint classification, and fingerprint comparison were developed.

For example, the (Federal Bureau of Investigation) FBI fingerprint identification division was set up in 1924 with a database of 810,000 fingerprint cards.

With the rapid expansion of fingerprint recognition in forensics, operational fingerprint databases became so huge that manual fingerprint identification became infeasible. For example, the total number of fingerprint cards (each card contains one impression for each of the 10 fingers of a person) in the FBI fingerprint database now stands well over 200 million from its original number of 810,000 and is growing continuously. With thousands of requests being received daily, even a team of more than 1,300 fingerprint experts were not able to provide timely responses to these requests (Lee and Gaensslen, 2001). Starting in the early 1960s, the FBI, Home Office in the UK, and Paris Police Department began to invest a large amount of effort in developing automatic fingerprint identification systems (Lee and Gaensslen, 2001).

Based on the observations of how human fingerprint experts perform fingerprint recognition, three major problems in designing (Automated Fingerprint Identification Systems) AFISs were identified and investigated: digital fingerprint acquisition, local ridge characteristic extraction, and ridge characteristic pattern matching. (Maltoni, Maio et al. 2009).

Their efforts were so successful that today almost every law enforcement agency worldwide uses an AFIS. These systems have greatly improved the operational productivity of law enforcement agencies and reduced the cost of hiring and training human fingerprint experts. Automatic fingerprint recognition technology has now rapidly grown beyond forensic applications into civilian and commercial applications. (Maltoni, Maio et al. 2009)

2.2.2. Early Cases Resulting in the Acceptance of Fingerprints:

1893 Argentina, June 19. In the small town of Necochea, two small children of young Francisca Rojas were murdered. Mrs. Rojas told the local police that she suspected a man named Velasquez who worked at a nearby ranch. Velasquez had threatened to kill the children when Mrs. Rojas, a widow, refused to marry him. Mrs. Rojas further stated that when she came home from work, Velasquez had run from her hut and passed her without a word. In the bedroom she found her children dead. Velasquez was arrested and denied the murders. The police chief had him beaten then bound and laid beside the corpses for a night. After a full week of brutal interrogation, he still denied the crime. It was learned that Francisca had a young lover who had said that he would marry her only if she did not have the children. The suspicions of the police focused on the mother. Police Inspector Alvarez was sent from La Plata to investigate the matter. He established that Velasquez and Mrs. Rojas's lover had been elsewhere at the time of the murder. In searching the scene of the crime, he observed bloody fingerprints on the door of the hut. He cut out two pieces of the door bearing the prints and, along with the known fingerprints of Mrs. Rojas and Velasques, sent them to the La Plata Central Identification Bureau and Juan Vucetich. The latent prints were identified as those of the mother and, when faced with this evidence, she confessed (Mark 2009).

1911 United States. Chicago police arrested a man named Thomas Jennings for murder. Jennings had murdered a man when he had been caught attacking the man's daughter. The evidence against Jennings was slim except for fingerprint evidence. The prosecution wanted to ensure the fingerprint evidence would be admitted before the Illinois Supreme Court, which had not previously ruled on the issue. To strengthen its case, the prosecution called several recognized fingerprint experts as witnesses. Among the expert witnesses was Mary E. Holland of Holland Detective Agency. As a result, Jennings was convicted and sentenced to hang on December 22, 1911. The aforementioned cases serve to illustrate, as with any new technology, that test cases must establish the viability of evidence (Mark 2009).

2.2.3. Erroneous Identification:

In 1998, the British court freed Danny McNamee who was convicting for a suspected Ireland Republic Army terrorist attack in 1982. An appeal was made, where 14 expert witnesses disagreed on the value of the fingerprint evidence. Some stated that the print had too poor quality for an identification, while others who made a positive identification could not find the 16 points of similarity (as the U.K. standard at the time advised). (Abraham 2017)

In 2004, Lana Canen was arrested and charged with the 2002 murder of Helen Sailors based on fingerprint evidence. Lana Canan was later convicted in 2005. In 2011, an independent fingerprint examiner was hired to re-examine the fingerprint evidence, who found the identification to be erroneous. After the Indiana State Police Crime Lab verified this error, Lana Canen was subsequently released from prison in 2012. (Abraham 2017)

Today we realize, without question, that fingerprints are one of the most damaging types of evidence that can be presented due to the individuality that can be established. In other words, fingerprints can be individualized to one source to the exclusion of all others.

2.3. Formation of Fingerprints:

Fingerprints are fully formed at about 7 months of fetus development (Davide, etal 2009). Finger ridge configurations do not change throughout the life of an individual except due to accidents such as bruises and cuts on the fingertips (Babler, 1991). This property makes fingerprints a very attractive biometric identifier. Biological organisms, in general, are the consequence of the interaction of genes and environment. It is assumed that the phenotype is uniquely determined by the interaction of a specific genotype and a specific environment. Physical appearance and fingerprints are, in general, a part of an individual's phenotype (Cummins and Midlo 1961).

Fingerprint formation is similar to the growth of capillaries and blood vessels in angiogenesis. The general characteristics of the fingerprint emerge as the skin on the fingertip begins to differentiate. The differentiation process is triggered by the growth in size of the volar pads on the palms, fingers, soles, and toes. However, the flow of amniotic fluids around the fetus and its position in the uterus change during the differentiation process. Thus the cells on the fingertip grow in a microenvironment that is slightly different from hand to hand and finger to finger. The finer details of the fingerprints are determined by this changing microenvironment. A small difference in microenvironment is amplified by the differentiation process of the cells. There are so many variations during the formation of fingerprints that it would be virtually impossible for two fingerprints to be exactly alike. But, because the fingerprints are differentiated from the same genes, they are not totally random patterns either. The extent of variation in a physical trait due to a random development process differs from trait to trait (Cummins and Midlo 1961).

Typically, most of the physical characteristics such as body type, voice, and face are very similar for identical twins and automatic recognition based on face and hand geometry will most likely fail to distinguish them. Although the minute details in the fingerprints of identical twins are different (Jain, Prabhakar et al. 2002), (2001). a number of studies have shown significant correlation in the fingerprint class (i.e., whorl, right loop, left loop, arch, tented arch) of identical (monozygotic) twin fingers;

correlation based on other generic attributes of the fingerprint such as ridge count, ridge width, ridge separation, and ridge depth has also been found to be significant in identical twins (Lin et al., 1982). In dermatoglyphics studies, the maximum generic difference between fingerprints has been found among individuals of different races. Unrelated persons of the same race have very little generic similarity in their fingerprints, parent and child have some generic similarity as they share half the genes, siblings have more similarity, and the maximum generic similarity is observed in monozygotic (identical) twins, which is the closest genetic relationship (Cummins and Midlo 1961).

2.4. Individuality of Fingerprints:

Fingerprint identification (individualization):

Fingerprint identification is based on two basic premises:

(i) Persistence: the basic characteristics of fingerprints do not change with time; and (ii) individuality: the fingerprint is unique to an individual. (Pankanti, Prabhakar et al. 2002)

Although the word "fingerprint" is popularly perceived as synonymous with individuality, uniqueness of fingerprints is not an established fact but an empirical observation. With the stipulation of widespread use of fingerprints, however, there is a rightfully growing public concern about the scientific basis underlying individuality of fingerprints. Lending erroneous legitimacy to these observations will have disastrous consequences, especially if fingerprints will be universally used to recognize citizens for reasons of efficiency, convenience, and reliability in guarding against security threats and identity fraud. Furthermore, automated fingerprint recognition systems do not appear to use all the available discriminatory information in the fingerprints, but only a parsimonious representation extracted by an automatic feature extraction algorithm (Maltoni, Maio et al. 2009).

The amount of distinctive information available in a fingerprint is also being questioned. Simon Cole in "The Myth of Fingerprints," The New York Times, May 13, 2001, stated that "*the fingerprints may be unique in the sense that, as Gottfried Wilhelm Leibniz argued, all natural objects can be differentiated if examined in enough detail*." (Cole 2006) further argues that uniqueness may be valid when entire prints are compared but not for prints depicting small portions of a finger; the print size is even more significant in the view of the newer chipbased fingerprint sensors that cover only a small portion of the finger (unlike the nail-to-nail rolled inked fingerprints used in many criminal investigations). (Maltoni, Maio et al. 2009)

Finally, the US Supreme Court Daubert versus. Merrell Dow Pharmaceuticals, hearing started a closer scrutiny of the UK Home Office observation in 1893 that fingerprints are unique. Although the Supreme Court approved that fingerprints are unique, it subsequently sought (through the United States Department of Justice) to sponsor a systematic study to examine a sound and certain scientific basis of fingerprint individuality information. The scientific basis of fingerprint individuality continues to be questioned in the courts of laws in the United States to this day. Thus, the uniqueness of fingerprints is neither a bygone conclusion nor has it been extensively studied in a systematic fashion. (Maltoni, Maio et al. 2009).

2.5. Definitions Associated with Fingerprints:

Harold Cummins coined the term dermatoglyphics in 1926, which is used for the studies of epidermal ridges on the non-hairy part of palm, fingers, toes, and soles. He found that the configurations of ridge pattern are determined partly by heredity and partly by accidental or environmental influence, which produce stress and tension in their growth during fetal life. It has been accepted and adopted internationally. (KC, Maharjan et al. 2018)

Fingerprint:

Fingerprint is a greasy and oily impression of the friction ridges of the finger. These friction ridges are raised portions of the epidermal part of the skin of the finger digits and palmar or plantar surface. (Patil, Malik et al. 2017).

Palm print:

Palm print is the skin patterns of a palm, composed of the physical characteristics of the skin patterns of a palm. (Zhang, Lu et al. 2018).

Friction skin:

This is skin on the inner hands and fingers, and on the bottom of the feet and toes, which is characterized by alternating strips of raised ridges and furrows arranged in a variety of patterns. The friction skin is found on both humans and anthropoids. In lower mammals, friction ridge patterns are sometimes similar to ours. Friction surfaces are sometimes padded in apes. The purpose of the friction skin, as the name implies, is to provide resistance so that those surfaces containing friction skin will be able to grasp objects. (Mark 2009).

Friction ridge:

A raised portion of the epidermis on the palmar or plantar skin, consisting of one or more connected ridge units. (Holder, Robinson et al. 2011).

Furrow:

Valleys or depressions between friction ridges. (Holder, Robinson et al. 2011)

The constancy (permanence) and uniqueness of friction ridges are: Friction skin is permanent. That is, the skin does not change under normal conditions from the time of formation until decomposition after death. The exception is that, like other parts of the anatomy, the fingerprints or friction skin will get larger as the body grows. The specific characteristics will remain the same, however. Friction skin will deteriorate with age as well as all skin, but classification and identification normally will not be affected. There is an adage that is often used to describe the permanence: *under normal wear and tear, the friction skin will remain unchanged throughout one's life (Allen Bayle)* (Mark 2009).

Friction skin destruction (temporary or permanent) encompasses:

An injury penetrating into the dermal layer (second layer of skin), through the dermal papillae, will result in the ridges not being regenerated. Scar tissue will form to the extent that the damage occurred, and only those ridges in the path of the injury should be permanently affected (Mark 2009).

Injuries to the epidermal layer (first or outer layer) will repair themselves as they were prior to the injury, for example, paper cuts. There are many instances in legend where allegedly people have sanded, burned, or surgically altered their fingerprints with permanent results. Self-induced injuries cannot remove all ridges or the hands would be too severely injured to be used. What one must understand is that friction ridges cover the entire surface of the inner hands and bottom of the feet. If the pattern area alone were disfigured, classification might be affected, but identification or individualization would not. In all likelihood, the pattern would be made more unique which would make identification and individualization that much easier (Mark 2009).

Other alterations to the friction skin whether it is surgical, occupational, or medical can have an impact on the appearance. Examples are:

Skin grafts would result in either the old pattern being regenerated as the graft skin wore away or the graft area remaining smooth. A new pattern would not occur.

Occupational wear might wear down the ridges, but the cessation of the work will result in the ridges becoming distinct again.

Disease can have an effect on the fingerprints as well; such as in the latter stages of leprosy, the skin may flake off and the pattern may be lost. Allergic reactions may have an effect on the ridges in that a temporary change may occur but when the reaction disappears, ridges should return to their configuration. Other conditions such as warts, creases, or calluses may be present but seldom affect classification and rarely, if ever, affect identification. (Mark 2009).

2.6. Fingerprint classification:

First level detail refers to the overall pattern formed by the flow of ridges on the fingerprint surface and is insufficient for identifications. Most fingerprints fall into one of three main pattern types: loops, arches, or whorls. Second level detail refers to the specific friction ridge deviations or minutiae, commonly known as Galton details. All minutiae are either ridge endings, bifurcations, dots, or combinations of these. Third level detail refers to the morphology of the ridges, including pore locations and edges. (Lam 2018).

Ridge characteristics or Galton details*:*

May take the following forms (Mark 2009):

1. Staple or recurve.

2. Convergence.

3. Appendage.

4. Bifurcation. (Figure 2.1)

5. Divergence.

6. Rod enclosed in recurving.

7. Enclosure or island.

8. Dot. (Figure 2.1)

9. Short ridge.

10. Long ridge.

11. Incipient ridges.

12. Ending ridge. (Figure 2.1)

Figure 2.1: Ridge endings, bifurcations, and dots

are the basic minutiae (ridges are shown in black); all other types are combinations of these (Lam 2018), (Champod, Lennard et al. 2017).

Pattern area: (Figure 2.2)

That part of a loop or whorl pattern in which appear the cores, deltas, and ridges. (The pattern areas of loops and whorls are enclosed by type lines—a plain arch pattern is often referred to as an absence of pattern due to the lack of deltas, type lines, or a defined core.) (Mark 2009).

Type lines: (Figure 2.2)

The two innermost ridges which start parallel, diverge, and surround or tend to surround the pattern area (Mark 2009).

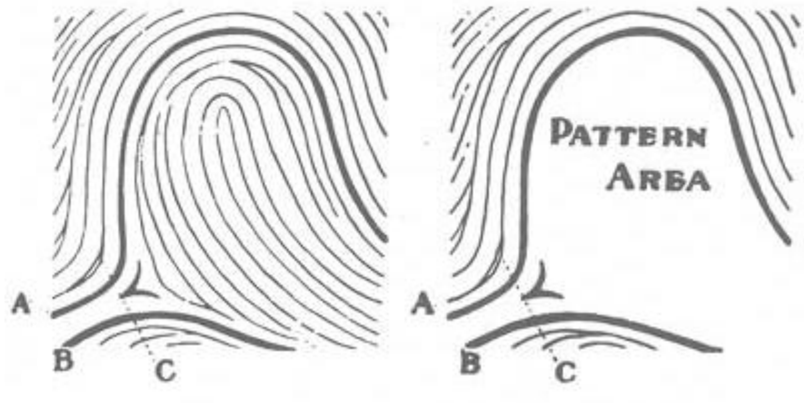

Figure 2.2: pattern area and type lines

Lines A and B, which have been emphasized in this sketch, are the type lines, starting parallel, diverging at the line C and surrounding the pattern area, which is emphasized by eliminating all the ridges within the pattern area. (Hoover 2006)

Core: (Figure 2.3)

1. The approximate center of a fingerprint pattern.

2. A specific formation within a fingerprint pattern, defined by classification systems such as Henry. *(Holder, Robinson et al. 2011)*

The delta: (Figure 2.3)

The point on a friction ridge at or nearest to the point of divergence of two type lines, and located at or directly in front of the point of divergence. Also known as a tri-radius.(Holder, Robinson et al. 2011)

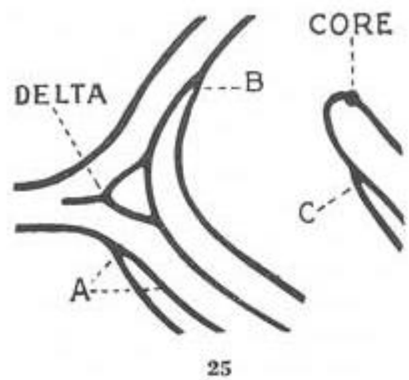

Figure 2.3: Core and delta.

Fig 2.3 shows ridge A bifurcating from the lower type line inside the pattern area. Bifurcations are also present within this pattern at points B and C. The bifurcation at the point marked "delta" is the only one which fulfills all conditions necessary for its location. It should be understood that the diverging type lines must be present in all delta formations and that wherever one of the formations mentioned in the definition of a delta may be, it must be located midway between two diverging type lines at or just in front of where they diverge in order to satisfy the definition and qualify as a delta. (Hoover 2006)

2.7. Fingerprint Pattern:

Fingerprints fall into one of three main pattern types: loops, arches, or whorls. (Lam 2018)

Loop Pattern:

A loop fingerprint (right loop and left loop) has one or more ridges that enter from left or right side, curve back and go back the same side they entered (Figure 2.4). (Dyre and Sumathi 2017).

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Figure 2.4: Loop pattern

(Hoover 2006)

Requirements of a loop: A loop pattern must possess the following essentials:

• A delta.

• A sufficient recurve.

• One or more ridge count across a looping ridge.

A sufficient recurve can be defined as that part of a recurving ridge between the shoulders of a loop that is free of any appendages abutting upon the outside of the recurve at right angles (Mark 2009).

The delta:

A delta may be:

• Bifurcation—to be chosen, the bifurcation must open toward the core.

• An abrupt ending ridge.

• A dot.

• A short ridge.

• A meeting of two ridges.

• A point on the first recurving ridge located nearest to the center and in front of the divergence of the type lines.

Radial and Ulnar Loops (RL&UL):

1. The terms have been derived from radial and ulnar bones of the forearm.

   a. Loops flowing in the direction of the little finger are ulnar loops.

   b. Loops flowing in the direction of the thumb are radial loops.

   c. For purposes of automated use, loops are termed either a right slanted (those patterns where ridges flow to the right) or left slanted (those patterns where ridges flow to the left) (Figure 2.5).

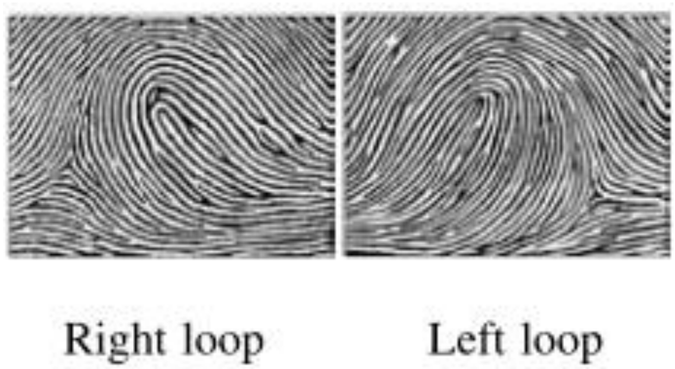


Figure 2.5: loop pattern

(Champod, Lennard et al. 2017)

Determining the direction of flow:

a. Begin at the core and follow or trace the ridges away from the delta.

b. From the recurve to the open end of loop.

The Whorl Pattern:

Definition: A whorl is that type of pattern in which at least two deltas are present with a recurve in front of each (Mark 2009).

Types: The plain whorl, the central pocket loop whorl, the double loop whorl, and the accidental whorl.

Plain Whorl:

The "plain whorl" consists of the simplest form of whorl construction and is the most common of the whorl subdivisions. It is designated by the symbol "W" for both general classification and extension purposes. (Hoover 2006).

The plain whorl has two deltas and at least one ridge making a complete circuit, which may be spiral, oval, circular, or any variant of a circle (Figure 2.6). An imaginary line drawn between the two deltas must touch or cross at least one of the recurving ridges within the inner pattern area. A recurving ridge, however, which has an appendage connected with it in the line of flow cannot be construed as a circuit. An appendage connected at that point is considered to spoil the recurve on that side. (Hoover 2006)

Figure 2.6: Plain whorl

(Hoover 2006)

Central Pocket Loop Whorl:

Combines the features of both loops and whorls.

1. The pattern looks like a loop but has a small whorl inside the loop ridges.
2. It has two deltas, one at the edge of the pattern area, and one inside the pattern area just below the centermost ridges (inner delta).

3. It fulfills the requirements of the loop with one or more whorl ridges around the core.

4. This pattern is sometimes called a bulb or flower for obvious reasons.

Definition: The central pocket loop has two deltas and at least one ridge making a complete circuit, which may be spiral, oval, circular, or any variant of a circle (Figure 2.7) (Mark 2009).

1. One or more of the simple recurves of the loop type usually recurve a second time to form a pocket within the loop (inside delta).

2. This does not have to be a continuation of the first ridge or connected to it. (Mark 2009)

Figure 2.7: central pocket whorl

(Hoover 2006)

Double Loop Whorl:

A double loop whorl is a pattern that consists of two separate loop formations with two separate and distinct sets of shoulders and two deltas (2 × 2 × 2) (Figure 2.8) (Mark 2009).

1. The loops may be connected by an appendaging ridge provided that it does not abut on the loop at right angles between the shoulders, spoiling it.

2. The loops do not have to conform to the ridge count requirement of a plain loop.

3. It is not essential that both sides of a loop be of equal size or length.

4. It is not material from which side the loops enter. The loops may enter from either side or both from the same side.

Figure 2.8: Double loop whorl

(Hoover 2006)

Accidental Whorl:

An accidental whorl is a pattern consisting of a combination of two different types of patterns, with the exception of the plain arch, with two or more deltas, or a pattern which possesses some of the requirements for two or more different types, or a pattern which conforms to none of the definitions (Figure 2.9) (Mark 2009).

Figure 2.9: Accidental whorl.

(Hoover 2006)

Examples:

Loop and Tented Arch (**Note:** The loop must appear over the tented arch. Where the loop does not appear in this position, the preferred pattern is a loop.)

If there is an issue between two types of patterns in the whorl pattern or ridges, which conform to more than one subdivision, the order of priority in preference is:

1. Accidental.
2. Double loop.
3. Central pocket loop.
4. Plain.

Plain Arch and Tented Arch Patterns:

The Plain Arch:

In plain arches, the ridges enter on one side of the impression and flow or tend to flow out the other with a rise or wave in the center. The plain arch is the most simple of all fingerprint patterns, and it is easily distinguished. It will be noted that there may be various ridge formations such as ending ridges, bifurcations, dots and islands involved in this type of pattern, but they all tend to follow the general ridge contour; i.e., they enter on one side, make a rise or wave in the center, and flow or tend to flow out the other side (Figure 2.10). (Hoover 2006)

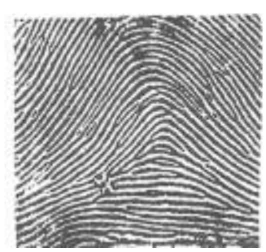


Figure 2.10: Plain Arch.

(Hoover 2006)

The Tented Arch:

In the tented arch, most of the ridges enter upon one side of the impression and flow or tend to flow out upon the other side, as in the plain arch type; however, the ridge or ridges at the center do not (Figure 2.11). There are three types of tented arches:

● The type in which ridges at the center form a definite angle; i.e., 90° or less.

● The type in which one or more ridges at the center form an upthrust. An upthrust is an ending ridge of any length rising at a sufficient degree from the horizontal plane; i.e., 45° or more.

● The type approaching the loop type, possessing two of the basic or essential characteristics of the loop, but lacking the third. (Hoover 2006)

Figure 2.11: Tented arch

(Hoover 2006)

2.8. Recording Legible Fingerprints:

The FBI's Integrated Automated Fingerprint Identification System (IAFIS) is the largest biometric database of criminals in the world. Clear, legible fingerprints form the foundation of the Fingerprint Master File, which continues to grow by approximately 13,000 records each day.

(www.fbi.gov/services/cjis/fingerprints-and-otherbiometrics/recording-legible fingerprints).

2.8.1 Fingerprint Impression Types:

Type 4:

Rolled impressions are the ten individually-taken fingerprint images rolled from nail to nail. The plain impressions are used to verify the sequence and accuracy of the rolled impressions. (www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints).

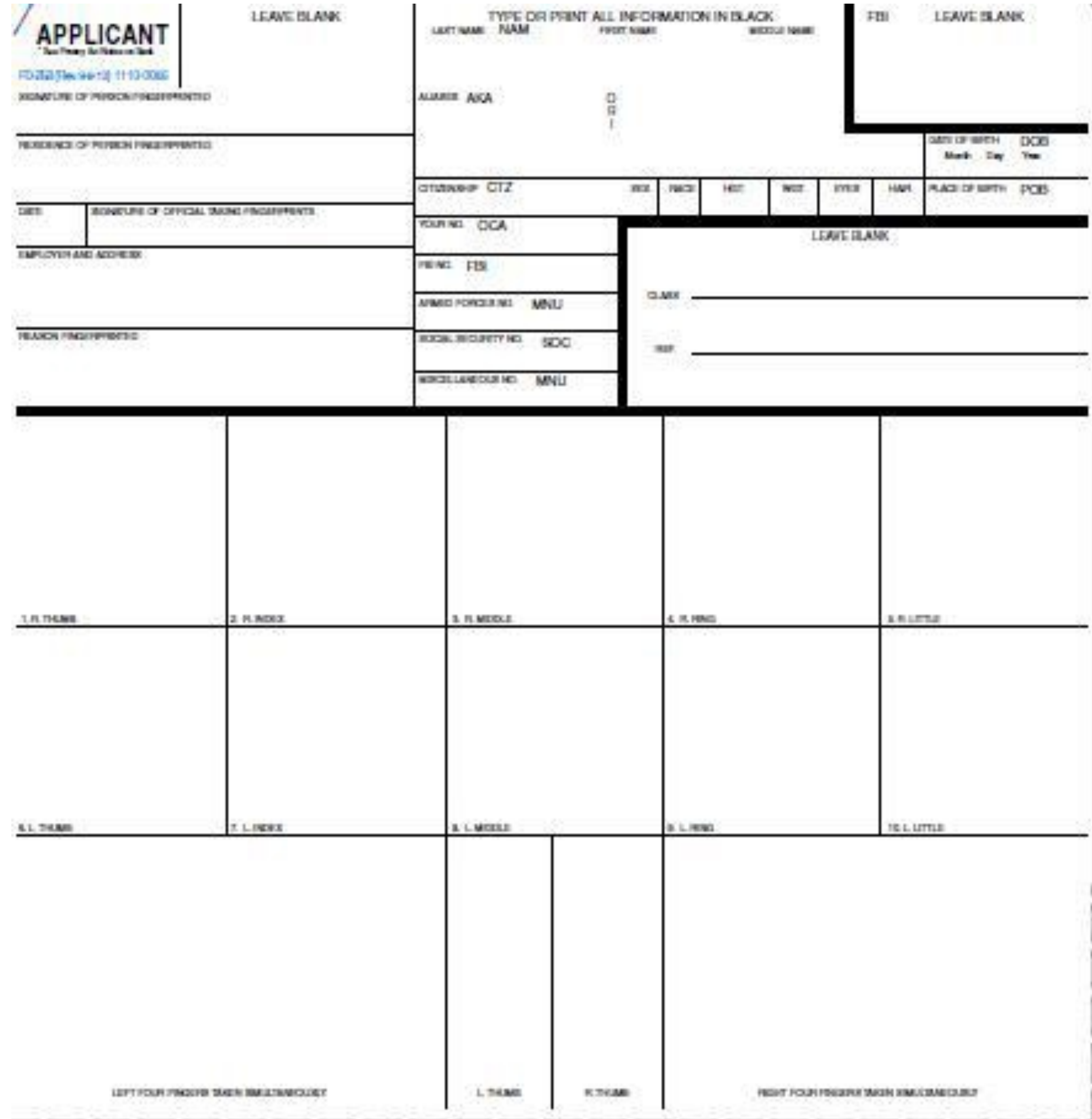
Type 14:

Identification flat impressions are taken simultaneously without rolling. These are referred to as plain, slap, or flat impressions. The individual's right and left four fingers should be captured first, followed by the two thumbs (4-4-2 method). Instituting this finger capture method ensures the highest level of fingerprint sequence accuracy. (https://www.fbi.gov/services/cjis/fingerprints-and-other biometrics/recording-legible fingerprints).

2.8.2. Basic Fingerprint Equipment:

Fingerprints can be recorded utilizing the following methods:

- Standard Fingerprint Card (e.g., FD-249 and FD-258)—Use ink to record fingerprint images on standard fingerprint cards.



APPLICANT

LEAVE BLANK

TYPE OR PRINT ALL INFORMATION IN BLACK

LAST NAME NAM FIRST NAME MIDDLE NAME

FBI LEAVE BLANK

SIGNATURE OF PERSON FINGERPRINTED

ALIASES AKA

O R I

RESIDENCE OF PERSON FINGERPRINTED

DATE OF BIRTH DOB Month Day Year

CITIZENSHIP CTZ SEX RACE HGT. WGT. EYES HAIR PLACE OF BIRTH POB

DATE SIGNATURE OF OFFICIAL TAKING FINGERPRINTS

YOUR NO. OCA

LEAVE BLANK

EMPLOYER AND ADDRESS

FBI NO. FBI

CLASS

ARMED FORCES NO. MNU

REASON FINGERPRINTED

SOCIAL SECURITY NO. SOC

REF.

MISCELLANEOUS NO. MNU

1. R. THUMB 2. R. INDEX 3. R. MIDDLE 4. R. RING 5. R. LITTLE

6. L. THUMB 7. L. INDEX 8. L. MIDDLE 9. L. RING 10. L. LITTLE

LEFT FOUR FINGERS TAKEN SIMULTANEOUSLY L. THUMB R. THUMB RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY

Figure 2.12: FD258

(www.copsplus.com/identicator-le-40a-applicant-fingerprint-cards-fd-258-for-le-10)

- Live Scan—Fingerprint images can be submitted electronically using a live scan device. Electronic fingerprinting equipment should be properly maintained at all times.

Figure 2.13 The high-resolution fingerprint scanner

(Zhang, Lu et al. 2018)

2.8.3. Fingerprinting Process:

1. The recommended height for recording legible fingerprints is approximately 39 inches from the floor. This allows the forearm of an average adult to be parallel with the floor. This is the recommended position to record fingerprints.
    a. Soap and water are preferred; however, rubbing alcohol may be substituted.
    b. If hands are moist, wipe each finger with rubbing alcohol. If hands are dry or flaky use a small amount of hand lotion and wipe off any residue.

   c. If capturing fingerprints electronically, ensure the live scan fingerprint device is properly calibrated and the platen is free of dust, dirt, and any residual fingerprint images.

2. The individual's hands should be cleaned prior to printing:
3. Instruct the individual to look away from the fingerprint device, not to assist in the fingerprint process, and to relax. Grasp the individual's right hand at the base of the thumb with your right hand. Cup your hand over the individual's fingers, tucking under those fingers not being printed. Guide the finger being printed with your left hand.
4. If using the ink and paper method, roll the finger on the inking plate or pad so the entire fingerprint pattern area is evenly covered with ink. The ink should cover from one edge of the nail to the other and from the crease of the first joint to the tip of the finger.
5. When taking the rolled impression, the side of the finger bulb is placed upon the card or platen. The finger is then rolled to the other side until it faces the opposite direction. Care should be exercised so the bulb of each finger, from tip to below the first joint, is rolled evenly. Generally, the weight of the finger is the maximum pressure needed to clearly record a fingerprint. In order to take advantage of the natural movement of the forearm, the hand should be rotated from the more difficult position to the easiest position. This requires the thumbs be rolled toward and the fingers away from the center of the individual's body. Roll each finger from nail to nail in the appropriate space, taking care to lift each finger up after rolling to avoid smudging.
6. When using the ink and paper method and a rolled impression is not acceptable, you may use an adhesive retab to cover the fingerprint in

its space. (Only two retabs can be applied to each fingerprint block.) For live scan, the image should be deleted and retaken.

7. For a Type-4, plain impressions are typically printed last. The technician simultaneously presses the individual's four fingers (of the right hand), keeping the fingers together on the surface of the card or live scan device (at a 45-degree angle) to capture all four fingers in the allotted space. Repeat this process for the left hand and then print both thumbs. Type-14 capture protocol requires the technician to simultaneously press the individual's four fingers on the surface of the live scan device at a 90-degree vertical angle. Care should be taken to capture all fingers in the allotted space. Repeat this process for the left hand and then print both thumbs simultaneously (4-4-2 method). Capturing all fingers and thumbs in a vertical position improves finger segmentation software accuracy
8. Complete all required textual information. It is important to enter the appropriate data in all fields when known. (www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints).

2.8.4. Special Circumstances:

Deformed or missing fingers:

If the finger is deformed, every attempt should be made to record the fingerprint in both the rolled and plain impression blocks. A postmortem kit, which is more commonly known as a spoon, can be utilized to assist in recording these images. If unable to record the image, simply place a notation in the fingerprint block (e.g., deformed, webbed).

Missing fingers are fingers physically present but cannot be recorded at the time of capture due to injury. Each missing finger should be designated via a notation in the fingerprint block (e.g., bandaged, injured, crippled, paralyzed). (https://www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints)

Fully amputated fingers:

An amputated finger occurs when the finger's first joint is no longer physically present. Amputated fingers should be designated via a notation in the fingerprint block (e.g., amp, missing at birth, severed).

Tip-amputated fingers:

If a portion of the first joint is present, record the available fingerprint pattern area in both the rolled and plain impression blocks. (https://www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints)

Extra fingers:

When fingerprinting an individual with an extra finger, record only the thumb and the next four fingers. Do not record the extra finger as either a rolled or plain impression. (https://www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints)

Scarred fingers:

Record scarred fingers in both the rolled and plain impressions without a notation. (https://www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints)

Worn fingerprints:

An individual, by the nature of their work or age, may have very thin or worn ridges in the pattern area. Apply light pressure and use very little ink to record these types of fingerprint impressions. A technique known as "milking the finger" can be used to raise the fingerprint ridges prior to

printing. This technique involves applying pressure or rubbing the fingers in a downward motion from palm to fingertip.
(https://www.fbi.gov/services/cjis/fingerprints-and-other-biometrics/recording-legible-fingerprints)

2.9. Previous studies:

Herman M. Slatis et al, at 1976 found that as the proportion of whorls among the parents increases, the proportion of children with whorls also increases.

Ching Cho (2000) (Cho 2000) on Finger Dermatoglyphics of Australian Aborigines in the Northern Territory of Australia found that whorls (56.7%) are more abundant than loops (42.6%) in males. Females exhibit a bit higher frequency of whorls (51.2%) and lower frequency of loops (47.0%)

Anil K. Jain (2002) (Jain, Prabhakar et al. 2002) on the similarity of identical twin fingerprints show that a state-of-the-art automatic fingerprint verification system can successfully distinguish identical twins though with a slightly lower accuracy than non-twins.

Jacob B. Adler (2003) asks Are There Genetic Relationships between Fingerprints in a Family? His data shows that there is indeed a relationship between fingerprints of people in a family. All of the groups of related people had more features in common than non related people. The data also suggests that fingerprints are passed down to a child in many cases through one parent more than the other parent, which is a typical pattern indicating the features are hereditary. (Adler 2003)

Most studies have shown ulnar loop as having the highest percentage in normal population followed by whorl, arch and radial loop (Oladipo and Akanigha 2005).

Mark 2009 found that 65% of fingerprints are loop pattern, 30% are whorl pattern, and only 5% are arch pattern.

Tanuj Kanchan, Saurabh Chattopadhyay (Kanchan and Chattopadhyay 2006) on Distribution of Fingerprint Patterns among Medical Students found that the distribution of fingerprint patterns was similar on both hands for both sexes. Thus while different patterns show preferences for different digits, bilateral variations in the Distribution of fingerprint patterns do not occur. No gender-based differences could be established.

Carly R. Dion (2012) in Fingerprint Patterns in Siblings says Fingerprint patterns do show similarity between siblings. Fingerprints may be unique, but fingerprint patterns will often lie within the same category as a sibling.(Dion 2012).

Jasmine M. Shapiro (2013) on Fingerprints: Similarities in Families find out There was more of a similarity between siblings than between parents are their children. The reason she came up with this hypothesis is because siblings share more of the same DNA with each other. Some siblings might have more DNA and similarity to one parent than the other, when siblings share DNA from both parents.(Shapiro 2013).

The dermatoglyhic pattern of the digits and palms of Nigerians residing in Lagos – Nigeria followed a particular pattern of percentage frequency which is ulnar loop > Whorls >ARchs> Radial loops (79.5%), 42.4%, 12.4%, 9.3% respectively).(Abue, Duru et al. 2013)

Nithin Mathew Sam, Rema P., Venugopalan Nair B (Sam, Rema et al. 2014) on Study of Fingerprint Patterns in South Indian Population found that in either sex, Loops were the predominant pattern in both genders, followed by whorls.

The distribution of primary pattern of fingerprint is not related to gender and ABO and Rh blood group, but its distribution is related to individual digits of both hands. (KC, Maharjan et al. 2018).

2.10 The Fingerprints-World-Map

www.handresearch.com/news/fingerprints-world-map-whorls-loops-arches.htm

Table 2.1 : Distribution of pattern type:

COUNTRY	WHORLS	ULNAR LOOPS	RADIAL LOOPS	ARCHES	PATTERN INDEX
	(2 triradii)	(1 triradius R-side)	(1 triradius U-side)	(No triradius)	
Ellice islands (N=114) (A. M. O. Veale and W. E. Adams, 1968);	67.8 %	30.2 %	0.7 %	1.3 %	**16.65**
Maori of New Zealand (N=216) (A. M. O. Veale and W. E. Adams, 1965);	66.9 %	32.3 %	0.3 %	0.5 %	**16.64**
New Guinea (N=166) (C.C. Plato & D.C. Gajdusek, 1972);	55.0 %	43.4 %	1.1 %	0.5 %	**15.45**
Malaysia (N=48) (E. Ismail et al., 2009);	~57 %	~36 %	~3.5 %	~2.5 %	**15.35**
China (N=693) (Xu Cheng et al., 2009);	48.6 %	44.9 %	2.7 %	3.8 %	**14.48**
Guatemala (N=100) (D.W. Herdegen, 2012);	47 %	48 %	2 %	3 %	**14.40**

Argentina (N=60) (J. Mavalwala, 1978);	45.8 %	50.2 %	2.0 %	2.0 %	**14.38**
Korea (N=6.141) (Sung-Bae Hwang et al., 2005);	45.3 %	48.8 %	3.1 %	2.8 %	**14.25**
Thailand (N=2202) (Sung-Bae Hwang et al., 2005);	45.2 %	49.5 %	1.5 %	3.8 %	**14.14**
Vietnam (N=135) (Hui Li et al., 2006);	46.0 %	46.9 %	1.7 %	5.4 %	**14.06**
Israel (N=1126) (E. Kobyliansky et al., 2004);	40.2 %	52.5 %	3.7 %	3.6 %	**13.66**
India (N=455) (S.V. Pakhale et al., 2012);	41.8 %	48.8 %	3.4 %	6.0 %	**13.58**
Yemen (N=240) (S. Micle & E. Kobyliansky, 1987	40.0 %	53.0 %	2.3 %	4.7 %	**13.53**
Iran (N=200) (M. Mehdipour & D.D. Farhud, 1978)	38.5 %	52.8 %	4.1 %	4.6 %	**13.39**
Iraq (N=107) (D.W. Herdegen, 2012);	38.1 %	54.1 %	3.5 %	4.3 %	**13.38**
Indonesia (N=2000) (K.-S. Park & H.Y. CHeon, 1984);	34.3 %	60.2 %	2.5 %	3.0 %	**13.13**
Sri Lanka (N=434) (B.T.W. Wijerathne, 2013);	35.5 %	57.7 %	2.0 %	4.8 %	**13.07**
Russia (N=547) (B. Kamakar et al., 2007);	34.4 %	57.3 %	2.8 %	5.5 %	**12.89**
Algeria (N=250) (N. Mortad et al., 2012);	34.3 %	57.2 %	3.0 %	5.5 %	**12.88**
Brazil (N=300) (E. de F. Penhalber et al., 1994);	30.8 %	60.0 %	4.3 %	4.9 %	**12.59**
Sweden	~29.2 %	~59.2 %	~4.5 %	7.1 %	**~12.21**

(N=120.000) (A. Rignell & K.E. Sjöqvist, 1983);					
England (N=6.300) (H. Cummins & C. Midlo, 1943);	25.6 %	63.9 %	5.6 %	4.9 %	**12.07**
Poland (N=300) (D.Z. Loesch, 1983);	25.6 %	63.5 %	5.3 %	5.6 %	**12.00**
France (N=76) (C. Berr et al., 1992);	26.6 %	60.7 %	~6.0 %	~6.7%	**~11.99**
US (N=1027) (B. Schaumann & M. Alter, 1976);	26.2 %	62.1 %	4.7 %	7.0 %	**11.92**
Norway (N=24.518) (M. Kuecken, 2004);	25.7 %	61.1 %	5.8 %	7.4 %	**11.83**
Netherlands (N=2.500) (A.G. de Wilde, 1986);	26.0 %	61.0 %	5.1 %	7.9 %	**11.81**
Nigeria (N=1216) (A.D. Abue et al., 2013	29.1 %	55.1 %	2.4 %	13.4 %	**11.57**
Kenya (N=304) (P.S. Igbigbi & B.C. Msamati, 2005);	18.2 %	71.3 %	6.5 %	4.0 %	**11.42**
Tanzania (N=300) (P.S. Igbigbi & B.C. Msamati, 2005);	18.3 %	70.3 %	7.1 %	4.3 %	**11.40**
Costa Rica (N=743) (Maia Segura - WW Ramiro Barrantes, 2009);	21.7 %	63.2 %	3.5 %	11.6 %	**11.01**
Venezuela (N=119) (A.G de Díaz Ungría, 1978);	23.8 %	56.3 %	1.4 %	18.5 %	**10.53**
Botswana (N=345) (K.-S. Park & H.Y. CHeon, 1984);[37]	16.1 %	64.2 %	3.3 %	16.4 %	**9.97**

Table 2.2: The most common fingerprint types for each single finger among 21 international populations:

(www.handresearch.com/news/fingerprints-world-map-whorls-loops-arches.htm)

COUNTRY	LEFT/RIGHT	THUMB	INDEX FINGER	MIDDLE FINGER	RING FINGER	PINKY
Ellice Islands (N=114)	right left	W W	W W	W W	W W	W W
Maori of New Zealand (N=216)	right left	W W	W W	W W	W W	W W
New Guinea (N=166)	right left	W W	W W	W W	W W	UL UL
Malaysia (N=48)	right left	W W	W W	W W	W W	W W
China (N=693)	right left	W W	W W	UL UL	W W	UL UL
Guatemala (N=100)	right left	W W	W W	UL UL	W W	UL UL
Argentina (N=60)	right left	W W	W UL	UL UL	W W	UL UL
Korea (N=6.141)	right left	W W	W W	UL UL	W W	UL UL
Thailand (N=2202)	right left	W W	W W	UL UL	W W	UL UL
Vietnam (N=135)	right left	W UL	W UL	UL UL	W W	UL UL
Israel (N=1126)	right left	W W	W W	UL UL	W W	UL UL
India (N=455)	right left	W W	W W	UL UL	W W	UL UL
Yemen (N=240)	right left	UL UL	W W	UL UL	W W	UL UL

Iran (N=200)	right left	W W	W W	UL UL	W W	UL UL
Iraq (N=107)	right left	W UL	W W	UL UL	W UL	UL UL
Indonesia (N=2000)	right left	UL? UL?	W?? W??	UL UL	W W?	UL UL
Sri Lanka (N=434)	right left	UL UL	UL W	UL UL	W W	UL UL
Russia (N=547)	right left	UL UL	UL UL	UL UL	W UL	UL UL
Algeria (N=250)	right left	W W	W UL	UL UL	UL UL	UL UL
Brazil (N=300)	right left	UL UL	W W	UL UL	UL UL	UL UL
Sweden (N=120.000)	right left	UL UL	W UL	UL UL	W UL	UL UL
England (N=6.300)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Poland (N=300)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
France (N=76)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
US (N=1027)	right left	UL UL	W/UL UL	UL UL	UL UL	UL UL
Norway (N=24.518)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Netherlands (N=2.500)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Nigeria (N=1216)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Kenya (N=304)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Tanzania (N=693)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Costa Rica (N=743)	right left	UL UL	UL UL	UL UL	UL UL	UL UL
Venezuela (N=119)	right left	W W	UL UL	UL UL	W UL	UL UL
Botswana	right	UL	UL	UL	UL	UL

(N=345)	left	UL	UL	UL	UL	UL
THE UNIVERSAL DISTRIBUTION FOR THE 10 FINGERS:	right left	W* W*	W* W*	UL* UL*	W* W*	UL* UL*

3. Materials and Methodology:

3.1. Study Design:

Comparative descriptive study aim to compare between the general fingerprints patterns of siblings and their parents.

3.2. Study area:

The study conducted in town of Jabal Awlya, 45 km to the south of Khartoum.

3.3. Study population:

All ten fingerprints from families, consisting of two biological parents (between 26 and 73 years old) and two sibling taken in this study. All siblings over 5 years old.

Any child less than 5years and any family less than four subject were excluded from the study.

3.4. Sample size:

384 person.

This sample size calculated from the following equation:

$$n = \frac{z^2\, p\, q}{d^2} = \frac{1.96x1.96x0.5x0.5}{0.5x0.5} = 384$$

In which n= Sample size, Z= standard deviation when significant level is 95% (1.96), P= Previous prevalence when there is no previous study it is (0.5), q= 1- p (0.5), d^2= desired margin of error (0.05). (Gregg 2008)

3.5. Materials and Equipments:

- Black inkpad.
- White paper.
- Paper towel.
- Moist towelettes for cleaning hands.
- Magnifying glass.

3.6. Methodology:

Principles:

- Fingerprints classified by pattern types, (loop, whorl, and arch).

Skills:

- Observing.
- Comparing and contrasting.
- Classifying.

Preparation:

Room Preparation:

Very little: Desks or tables to work at and good lighting.

Safety Precautions:

Soap and water and washcloths on hand for clean-ups and expect a mess, as ink will get onto faces, clothing, and surfaces.

Procedures and Activity:

To do this study we follow these steps:

1. To collect samples. Two trained assistant help us in this step.
    a. Moist towelettes used to clean the person's finger.

b. Thoroughly the fingers dried with a paper towel.
c. The fingers rolled on a black inkpad.
d. Then the inked fingers rolled onto white paper using light but constant pressure.
e. Other towelettes used to clean the person's inked finger.

2. Each fingerprint examined with magnifying glass and categorized as a whorl, arch, or loop pattern.
3. Fingerprints patterns of the sibling compared to each other and to their parents.

3.7. Data analysis:

1- Excel

2- SPSS version 22. (Descriptive analysis, cross tables, t test, and chi squire tests were used in this study).

3.8. Ethical considerations:

An ethical clearance obtained from the Jabal Awlia locality.

All individuals informed about the research objectives and procedures during the interview period. A signed consent form obtained from each individual included in the research.

4. Result:

This study of 4000 fingers of 100 families distributed in four groups, fathers group (100), mothers group (100) and two siblings groups (sib1 (100) and sib2 (100)). The variation in percentage of various patterns of fingerprint among subgroups. Number/ frequency and percentage of various patterns of overall and different subgroup were calculated and compared in Table 4.1 to 4.4.

Legend:

RT= right thumb, RI= right index, RM= right middle, RR= right ring, RL= right little, LT= left thumb, LI= left index, LM= left middle, LR= left ring, LL= left little fingers.

Table 4.1: Frequencies of loop pattern

LOOP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Father	58	50	69	56	75	64	56	65	53	80	**626**
Mother	60	67	72	62	81	64	62	72	58	83	**681**
Sib1	63	59	76	50	77	56	58	66	55	77	**637**
Sib2	53	62	64	41	73	52	54	56	53	81	**589**
TOTAL	**234**	**238**	**281**	**209**	**306**	**236**	**230**	**259**	**219**	**321**	**2533**

N = 400

Out of total 4000 fingers, 2533 (63.3%) was loops pattern. Among groups, table 4.1 shows that the fathers had 626 (62.6 %) out of 1000 fingers, mothers 681 (68%), sib1 637 (63.7%) and sib2 589 (60 %) loop pattern.

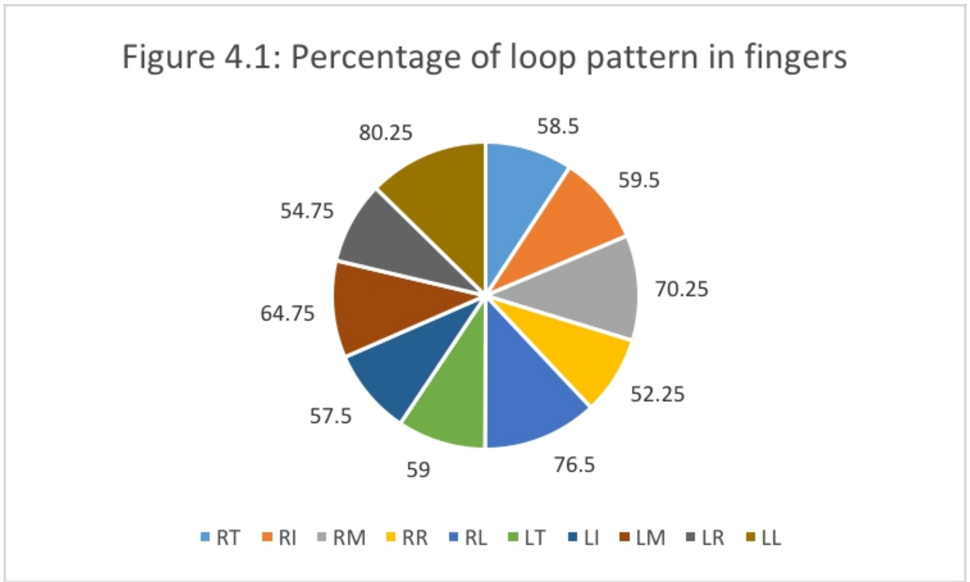


Figure 4.1: Percentage of loop pattern in fingers

N = 400

Table 4.2: Frequencies of whorl pattern:

WHORL	**RT**	**RI**	**RM**	**RR**	**RL**	**LT**	**LI**	**LM**	**LR**	**LL**	**TOTAL**
Father	38	42	25	42	24	31	35	25	45	18	**325**
Mother	32	29	19	36	19	32	31	21	40	15	**274**
Sib1	35	36	21	46	22	39	35	27	42	22	**325**
Sib2	38	32	30	54	22	38	36	36	44	19	**349**
TOTAL	**143**	**139**	**95**	**178**	**87**	**140**	**137**	**109**	**171**	**74**	**1273**

N = 400

Out of total 4000 fingers, 1273 (31.82%) was whorl pattern. Among groups, table 4.2 shows that the fathers had 325 (32.5 %) out of 1000 fingers, mothers 274 (27.4%), sib1 325 (32.5%) and sib2 349 (34.9 %) whorl pattern.

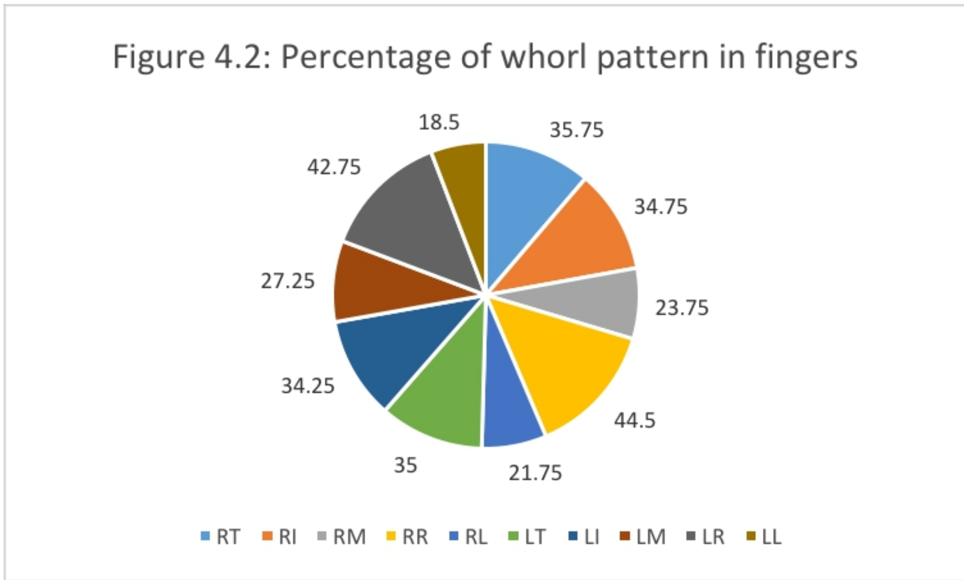


Figure 4.2: Percentage of whorl pattern in fingers

N = 400

Table 4.3: Frequencies of arch pattern:

ARCH	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Father	4	7	6	2	1	5	9	9	2	2	**47**
Mother	7	4	9	2	0	4	7	7	2	2	**44**
Sib1	2	5	3	4	1	5	7	7	3	1	**38**
Sib2	9	6	6	5	5	10	10	8	3	0	**62**
TOTAL	**22**	**22**	**24**	**13**	**7**	**24**	**33**	**31**	**10**	**5**	**191**

N = 400

Out of total 4000 fingers, 191 (4.77%) was arch pattern. Among groups, table 4.1 shows that the fathers had 47 (4.7 %) out of 1000 fingers, mothers 44 (4.4%), sib1 38 (3.8%) and sib2 62 (6.2 %) whorl pattern.

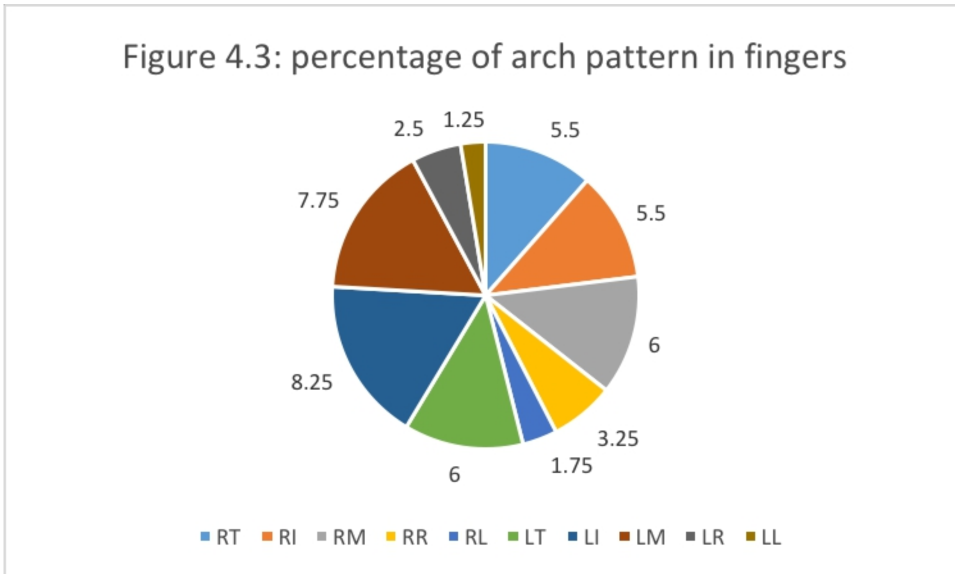


Figure 4.3: percentage of arch pattern in fingers

N = 400

Table 4.4: Unprinted fingers

Unprinted	RT	RI	LM	TOTAL
Father		1	1	**2**
Mother	1			**1**
Total	**1**	**1**	**1**	**3**

Out of 4000 fingers 3 fingers were unprinted 2 amputated fingers in fathers group in right index and left middle fingers, while 1unprinted in mothers group in the right thumb finger due to recent burn.

Table 4.5: Right and left hand finger asymmetry correlation

Finger	**Thumb**		**Index**		**Middle**		**Ring**		**Little**	
	Co	**sig**	**Co**	**sig**	**Co**	**sig**	**co**	**Sig**	**Co**	**sig**
Father	.720	.000	.338	.001	.457	.000	.396	.000	485	.000
Mother	.538	.000	.441	.000	.386	.000	.509	.000	.833	.000
Sib1	.510	.000	.555	.000	.604	.000	.630	.000	.654	.000
Sib2	.702	.000	.380	.000	.574	.000	.562	.000	.313	.002

N = 400

Correlation between right and left hand shows significant positive relations in all fingers. Fathers and sib2 shows high correlation in thumb 0.720 and 0.702 respectively. Mothers and sib1 groups shows high correlation in little fingers 0.833and 0.654 respectively.

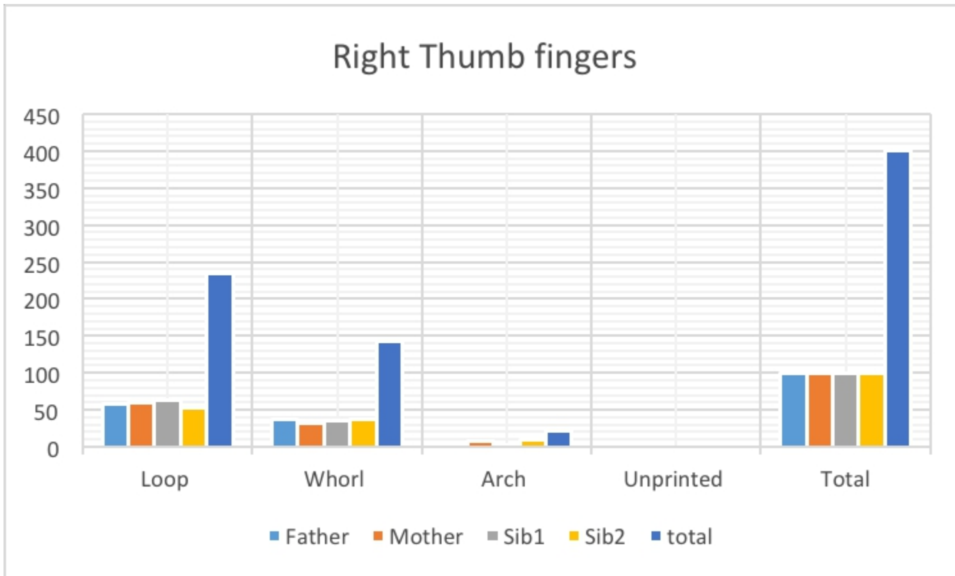


Figure 4.4: Right thump fingerprint patterns distribution

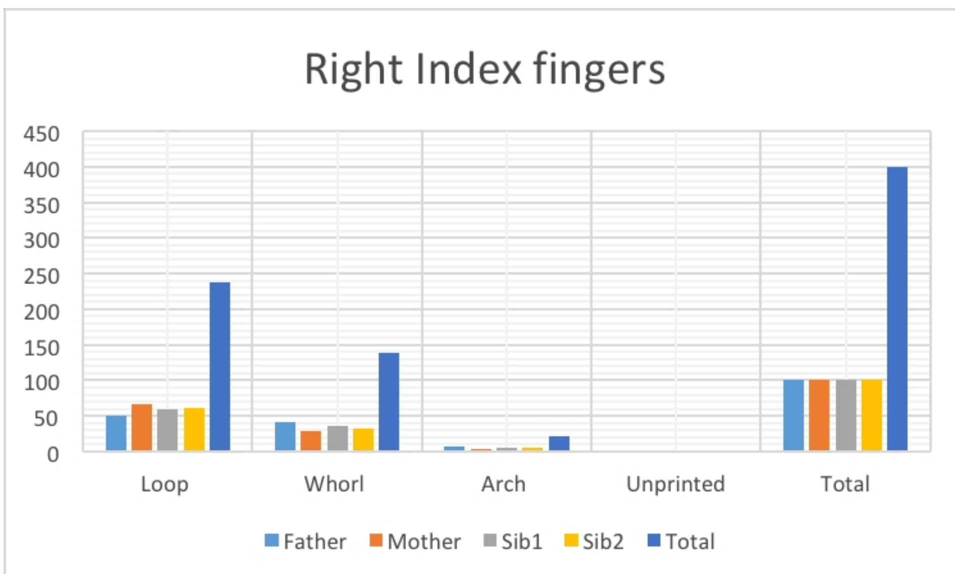


Figure 4.5: Right index fingerprint patterns distribution

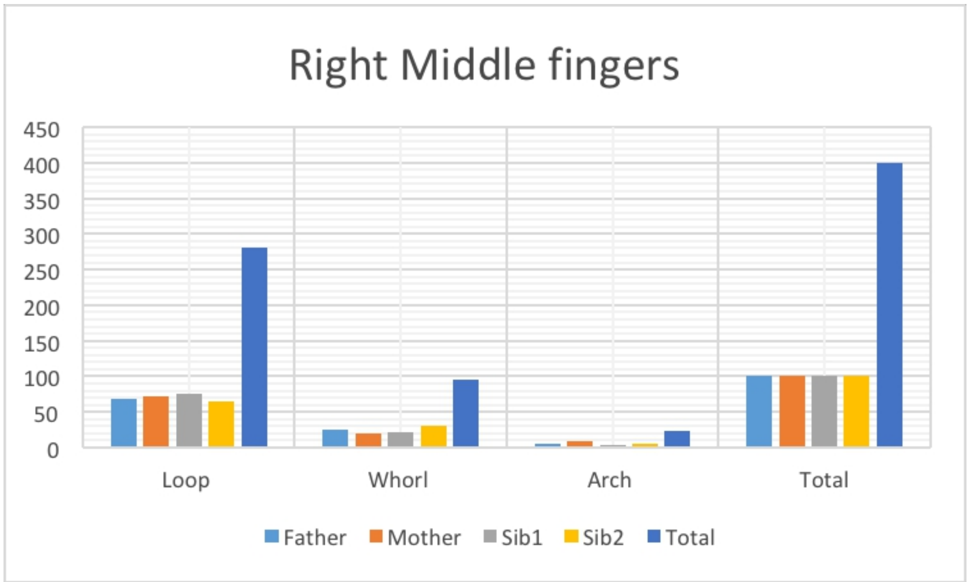


Figure 4.6: Right middle fingerprint patterns distribution

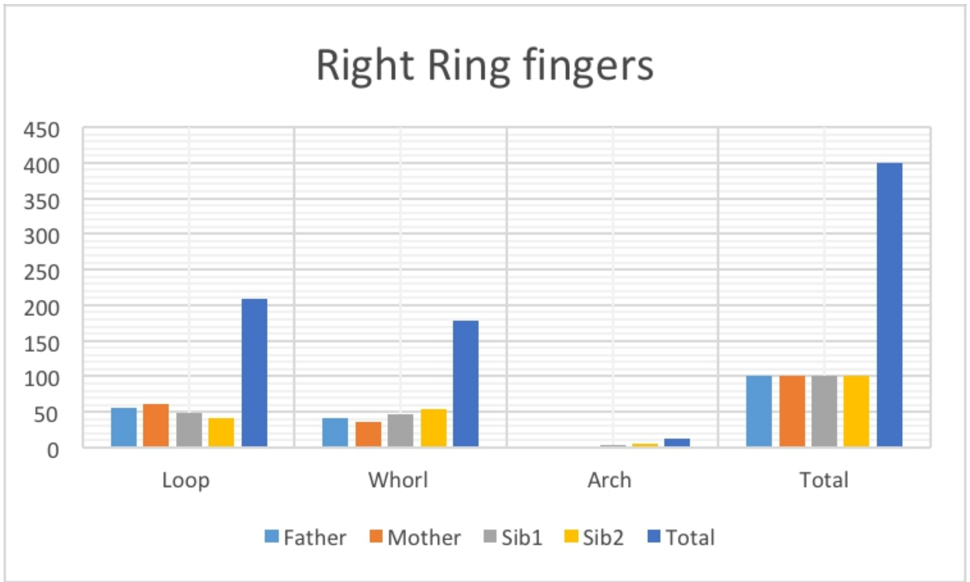


Figure 4.7: Right ring fingerprint patterns distribution

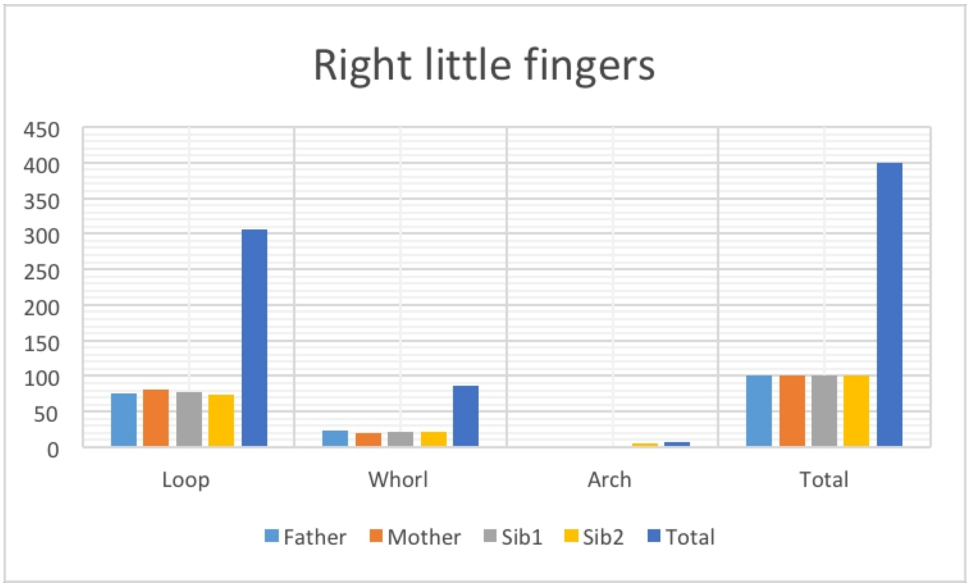


Figure 4.8: Right little fingerprint patterns distribution

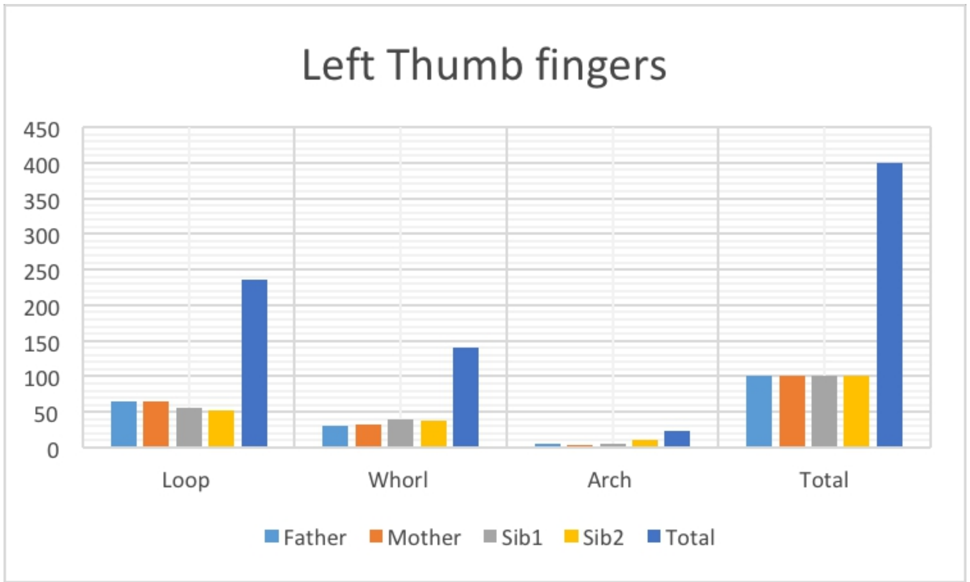


Figure 4.9: Left thumb fingerprint patterns distribution

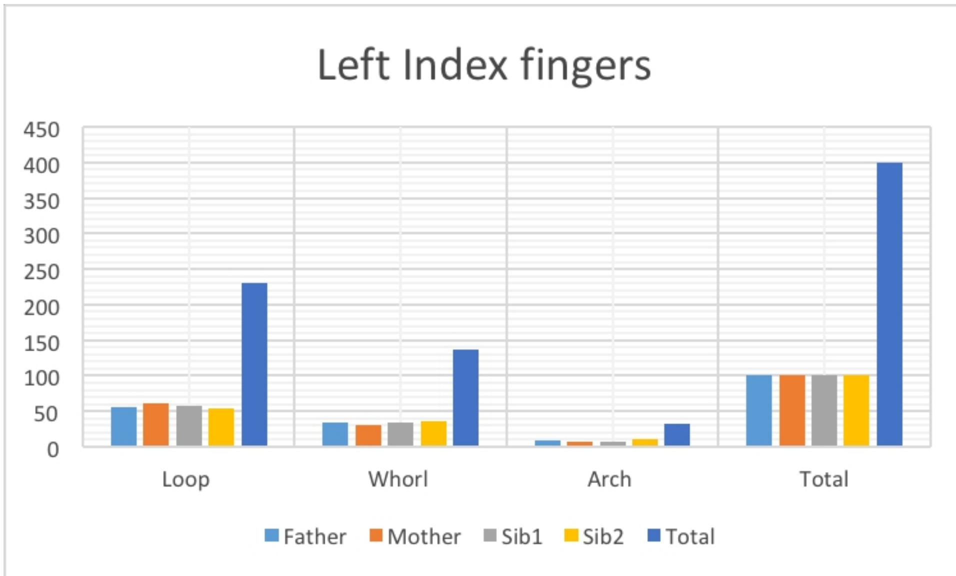


Figure 4.10: Left index fingerprint patterns distribution

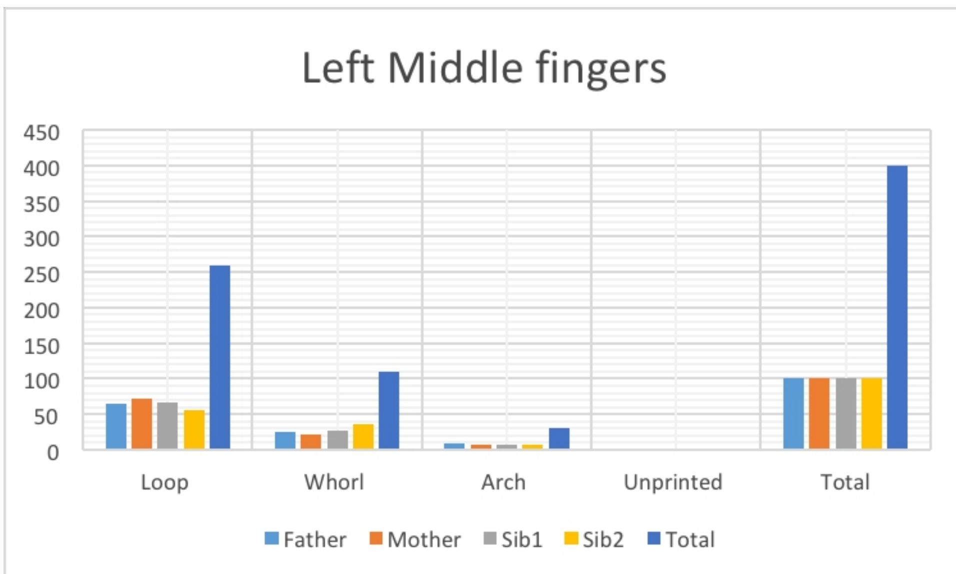


Figure 4.11: Left middle fingerprint patterns distribution

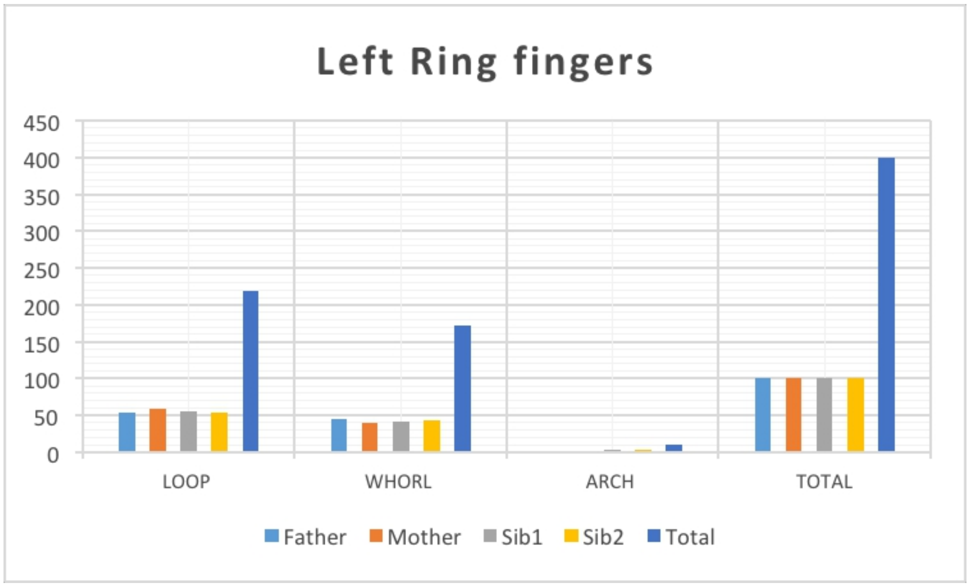


Figure 4.12: Left ring fingerprint patterns distribution

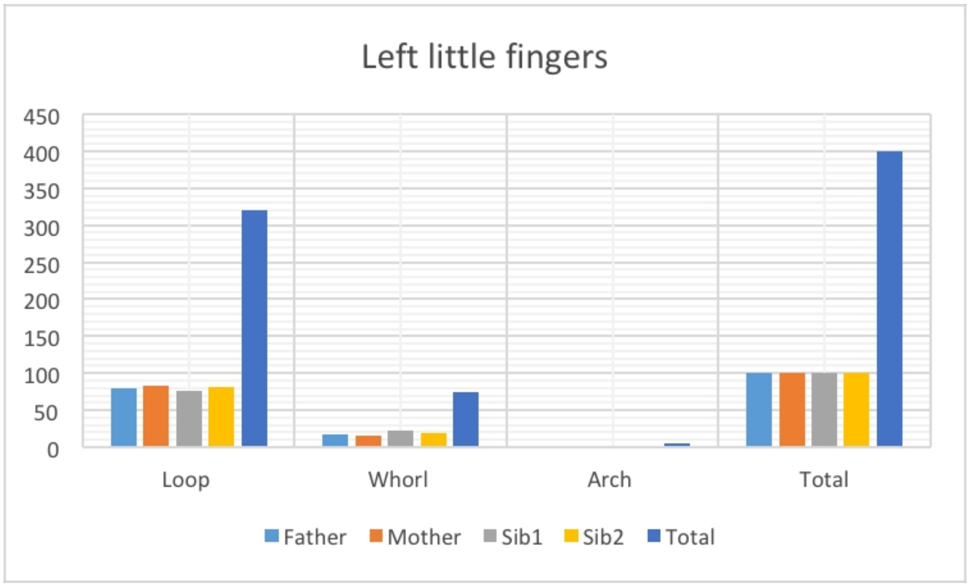


Figure 4.13: Left little fingerprint patterns distribution

Table 4.6: Sibling 1: gender frequencies

Gender	Frequency	Percent
Male	28	28
Female	72	72
Total	100	100

Table 4.7.A: Sibling 1: Male fingerprint patterns frequencies

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	16	18	24	11	21	19	19	22	13	23	**186**	**66**
Whorl	12	9	4	17	7	8	7	5	15	5	**89**	**32**
Arch	0	1	0	0	0	1	2	1	0	0	**5**	**2**
Total	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**280**	**100**

Table 4.7.B: Sibling 1: Female fingerprint patterns frequencies

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	47	41	52	39	56	37	39	44	42	54	**451**	**63**
Whorl	23	27	17	29	15	31	28	22	27	17	**236**	**33**
Arch	2	4	3	4	1	4	5	6	3	1	**33**	**4**
Total	**72**	**72**	**72**	**72**	**72**	**72**	**72**	**72**	**72**	**72**	**720**	**100**

From tables 4.7.A and 4.7.B the loop pattern high in male 66%, more than female 63%, while arch pattern was high in female 4% than male 2%.

Table 4.8.A: Sibling 1: Male fingerprint patterns similarity with father

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	**14**	10	16	9	17	16	12	17	7	16	**134**
Whorl	9	6	3	8	4	2	5	3	7	0	**47**
Arch	0	0	0	0	0	0	1	0	0	0	**1**
Total	**23**	**16**	**19**	**17**	**21**	**18**	**18**	**20**	**14**	**16**	**182**
%	**82**	**57**	**67.8**	**60.7**	**75**	**64**	**64**	**71.4**	**50**	**57**	**65**

Out of 280 fingers of male in sib1 group, 182 (65%) show similar fingerprint pattern types with their fathers. The higher similarity percent found in right thumb 82% and lower 50% in left ring fingers. 134 (72%) loop pattern out of 186, 47 (53%) whorl pattern out of 89, and 1 (20%) arch pattern out of 5 were similar to father's pattern types.

Table 4.8.B: Sibling 1: Female fingerprint patterns similarity with father

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	30	27	42	25	47	27	27	32	29	48	**334**
Whorl	12	20	9	17	8	18	16	14	19	7	**140**
Arch	0	0	1	0	0	1	0	0	0	1	**3**
Total	**42**	**47**	**52**	**42**	**55**	**46**	**43**	**46**	**48**	**56**	**477**
%	**58**	**65**	**72**	**58**	**76**	**63**	**59.7**	**63.8**	**66.6**	**77.7**	**66**

Out of 720 fingers of female in sib1 group, 477 (66%) show similar fingerprint pattern types with their fathers. The higher similarity percent found in left little fingers 77.7% and lower 58% in right thumb and right ring fingers. 334 (74%) loop pattern out of 451, 140 (59%) whorl pattern out of 236, and 3 (9%) arch pattern out of 33 were similar to father's pattern types.

Table 4.8.C: Sibling 1 fingerprint patterns similarity with father

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	44	37	58	34	64	43	39	49	36	64	**468**
Whorl	21	26	12	25	12	20	21	17	26	7	**187**
Arch	0	0	1	0	0	1	1	0	0	1	**4**
Total	**65**	**63**	**71**	**59**	**76**	**64**	**61**	**66**	**62**	**72**	**659**

Sibling1 group shows similar fingerprint pattern in 659 fingers, 468 as matching loop patterns, 187 as whorl, and 4 arch pattern types and the percent of similarity was 65.9% with higher similarity in the right and left little fingers.

Table 4.8.D: Similarity correlation between sibling 1 and father

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	.234	.019
Pair 2	R index & R index	100	.175	.082
Pair 3	R middle & R middle	100	.199	.047
Pair 4	R ring & R ring	100	.200	.046
Pair 5	R little & R little	100	.278	.005
Pair 6	L thump & L thump	100	.229	.022
Pair 7	L index & L index	100	.123	.223
Pair 8	L middle & L middle	100	.003	.974
Pair 9	L ring & L ring	100	.216	.031
Pair 10	L little & L little	100	.181	.071

The non-significant p value found in right index, left index, left middle and left little fingers while other fingers show significant p value. All ten fingers had a positive correlation with father's finger.

Table 4.9.A: Sibling 1: Male fingerprint patterns similarity with mother

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	9	13	16	10	17	13	12	16	8	19	**133**
Whorl	3	6	3	9	2	3	4	3	7	1	**41**
Arch	0	0	0	0	0	0	0	0	0	0	**0**
Total	**12**	**19**	**19**	**19**	**19**	**16**	**16**	**19**	**15**	**20**	**174**
%	**42.8**	**67.8**	**67.8**	**67.8**	**67.8**	**57**	**57**	**67.8**	**53.5**	**71**	**62**

Out of 280 fingers of male in sib1 group, 174 (62%) show similar fingerprint pattern types with their mothers. The right index, middle, ring, little, and left middle fingers found to be had the same matching percent 67.8% while the right thumbs were the lower percent 42.8%. 133 (72%) loop pattern out of 186, 41 (46%) whorl pattern out of 89 similar to pattern types of mothers group, and arch pattern do not match mothers.

Table 4.9.B: Sibling 1: Female fingerprint patterns similarity with mother

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	34	34	43	30	51	28	30	37	32	48	**367**
Whorl	12	11	7	18	8	16	15	11	18	6	**122**
Arch	0	0	0	0	0	0	1	1	0	0	**2**
Total	**46**	**45**	**50**	**48**	**59**	**44**	**46**	**49**	**50**	**54**	**491**
%	**63.8**	**62.5**	**69.4**	**66.6**	**81.9**	**61**	**63.8**	**68**	**69**	**75**	**68**

Out of 720 fingers of female in sib1 group, 491 (68%) show similar fingerprint pattern types with their mothers. The right little fingers found to be had the higher matching percent 81.9 % while the left thumbs were the lower percent 61%. 367 (81.3%) loop pattern out of 451, 122 (51.6%) whorl pattern out of 236, and 2 (6%) arch pattern out of 33 were similar to mother's pattern types.

Table 4.9.C: Sibling 1 fingerprint patterns similarity with mother

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	43	47	59	40	68	41	42	53	40	67	**500**
Whorl	35	17	10	27	10	19	19	14	25	7	**183**
Arch	0	0	0	0	0	0	1	1	0	0	**2**
Total	**78**	**64**	**69**	**67**	**78**	**60**	**62**	**68**	**65**	**74**	**685**

Sibling 1 groups shows similar fingerprint pattern in 685 fingers, 500 as matching loop patterns, 183 as whorl, and 2 arch pattern types and the percent of similarity was 68.5% with higher similarity in the right thumb and right little fingers.

Table 4.9.D: Similarity correlation between sibling 1 and mother

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	.195	.052
Pair 2	R index & R index	100	.242	.015
Pair 3	R middle & R middle	100	.062	.542
Pair 4	R ring & R ring	100	.244	.014
Pair 5	R little & R little	100	.308	.002
Pair 6	L thump & L thump	100	.102	.314
Pair 7	L index & L index	100	.127	.207
Pair 8	L middle & L middle	100	.097	.335
Pair 9	L ring & L ring	100	.265	.008
Pair 10	L little & L little	100	.123	.222

The non-significant p value found in right middle, left thumb, left index, left middle and left little fingers while other fingers show significant p value. All ten fingers had a positive correlation with mother's finger

Table 4.10: Sibling 2: gender frequencies

Gender	Frequency	Percent
Male	45	45
Female	55	55
Total	100	100

Table 4.11.A: Sibling 2: Male fingerprint patterns frequencies

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	25	24	26	13	31	24	25	26	19	33	**246**	**54.6**
Whorl	18	17	19	32	13	17	19	18	26	12	**191**	**42.4**
Arch	2	4	0	0	1	4	1	1	0	0	**13**	**2.8**
Total	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**450**	**100**

Table 4.11.B: Sibling 2: Female fingerprint patterns frequencies

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	28	38	38	28	42	28	29	30	34	48	**343**	**62.3**
Whorl	20	15	11	22	9	21	17	18	18	7	**158**	**28.7**
Arch	7	2	6	5	4	6	9	7	3	0	**49**	**8.9**
Total	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**55**	**550**	**100**

From table 11.A and 11.B the loop pattern high in female 62.3% more than male 54.6%, arch pattern was high in female 8.9% than male 2.8%. While whorl pattern was high in male 42.4 than female 28.7.

Table 4.12.A: Sibling 2: Male fingerprint patterns similarity with father

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	16	11	20	8	25	17	18	21	15	27	**178**	**63**
Whorl	9	10	8	16	5	13	10	8	19	5	**103**	**36**
Arch	0	0	0	0	0	1	0	1	0	0	**2**	**1**
Total	**25**	**21**	**28**	**24**	**30**	**31**	**28**	**30**	**34**	**32**	**283**	**100**
%	**55.5**	**47**	**62**	**53**	**67**	**69**	**62**	**67**	**75.5**	**71**	**63**	**100**

Out of 450 fingers of male in sib2 group, 283 (63%) show similar fingerprint pattern types with their fathers. The higher similarity percent found in left ring fingers 75.5% and lower 47% in right index fingers. 178 (72%) loop pattern out of 246, 103 (54%) whorl pattern out of 191, and 1 (8%) arch pattern out of 13 were similar to father's pattern types.

Table 4.12.B: Sibling 2: female fingerprint patterns similarity with father

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	20	25	31	17	32	23	22	21	22	42	**255**	**72.6**
Whorl	12	11	8	11	4	10	11	8	10	1	**86**	**24.5**
Arch	1	0	1	0	0	0	4	2	0	2	**10**	**2.8**
Total	**33**	**36**	**40**	**28**	**36**	**33**	**37**	**31**	**32**	**45**	**351**	**100**
%	**60**	**65**	**72.7**	**50.9**	**65**	**60**	**67**	**56**	**58**	**81.8**	**63.8**	

Out of 550 fingers of female in sib1 group, 351 (64%) show similar fingerprint pattern types with their fathers. The higher similarity percent found in left little fingers 81.8% and lower 50.9% in right ring fingers. 255

(74%) loop pattern out of 343, 86 (55%) whorl pattern out of 158, and 10 (20%) arch pattern out of 49 were similar to father's pattern types.

Table 4.12.C: Sibling 2: fingerprint patterns similarity with father

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	36	36	51	25	57	40	40	42	37	69	**433**
Whorl	21	21	16	27	9	23	21	16	29	6	**189**
Arch	1	0	1	0	0	1	4	3	0	2	**12**
total	**58**	**57**	**68**	**52**	**66**	**64**	**65**	**61**	**66**	**77**	**634**

Sibling 2 group shows similar fingerprint pattern in 634 fingers, 433 as matching loop patterns, 189 as whorl, and 12 arch pattern types and the percent of similarity was 63.4% with higher similarity in the left little fingers.

Table 4.12.D: Similarity correlation between sibling 2 and father

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	.140	.165
Pair 2	R index & R index	100	.051	.616
Pair 3	R middle & R middle	100	.180	.073
Pair 4	R ring & R ring	100	-.014-	.888
Pair 5	R little & R little	100	.026	.796
Pair 6	L thump & L thump	100	.083	.413
Pair 7	L index & L index	100	.396	.000
Pair 8	L middle & L middle	100	.181	.072
Pair 9	L ring & L ring	100	.284	.004
Pair 10	L little & L little	100	.323	.001

Left ring and left little fingers had a significant p value while other fingers were non-significant. Right ring show negative correlation and other fingers show positive correlation with father fingers.

Table 4.13.A: Sibling 2: Male fingerprint patterns similarity with mother

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	17	15	23	12	27	18	20	24	17	30	**203**
Whorl	8	8	8	15	4	9	9	8	19	4	**92**
Arch	0	1	0	0	0	0	1	0	0	0	**2**
Total	**25**	**24**	**31**	**27**	**31**	**27**	**30**	**32**	**36**	**34**	**297**
%	**55.5**	**53**	**68.8**	**60**	**68.8**	**60**	**66.6**	**71**	**80**	**75.5**	

Out of 450 fingers of male in sib2 group, 297 (66%) show similar fingerprint pattern types with their mothers. The left ring fingers found to be had the higher percent 80% while the right index were the lower percent 53%. 203 (82.5%) loop pattern out of 246, 92 (48%) whorl pattern out of 191, and 2 (15%) arch pattern out of 13 similar to pattern types of mothers group.

Table 4.13.B: Sibling 2: Female fingerprint patterns similarity with mother

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	21	32	28	22	35	20	20	23	24	43	**268**
Whorl	11	5	2	14	4	10	10	6	9	3	**74**
Arch	2	0	2	2	0	2	2	2	0	0	**12**
Total	34	37	32	38	39	32	32	31	33	46	**354**
%	**61.8**	**67**	**58**	**69**	**70.9**	**58**	**58**	**56**	**60**	**83.6**	**64**

Out of 550 fingers of female in sib2 group, 354 (64%) show similar fingerprint pattern types with their mothers. The left little fingers found to be had the higher matching percent 83.6 % while the left middle were the lower percent 56%. 268 (78%) loop pattern out of 343, 74 (46.8%) whorl pattern out of 158, and 12 (24%) arch pattern out of 49 were similar to mother's pattern types.

Table 4.13.C: Sibling 2: fingerprint patterns similarity with mother

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	38	47	51	34	62	38	40	47	41	73	**471**
Whorl	19	13	10	29	8	19	19	14	28	7	**166**
Arch	2	1	2	2	0	2	1	2	0	0	**12**
Total	**59**	**61**	**63**	**65**	**70**	**59**	**60**	**63**	**69**	**80**	**649**

Sibling 2 group shows similar fingerprint pattern in 649 fingers, 471 as matching loop patterns, 166 as whorl, and 12 arch pattern types. The percent of similarity was 64.9% with higher similarity in the left and right little fingers.

Table 4.13.D: Similarity correlation between sibling 2 and mother

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	.195	.051
Pair 2	R index & R index	100	.257	.010
Pair 3	R middle & R middle	100	.218	.029
Pair 4	R ring & R ring	100	.375	.000
Pair 5	R little & R little	100	.087	.390
Pair 6	L thump & L thump	100	.154	.126
Pair 7	L index & L index	100	.139	.166
Pair 8	L middle & L middle	100	.253	.011
Pair 9	L ring & L ring	100	.336	.001
Pair 10	L little & L little	100	.428	.000

The non-significant p value found in right little, left thumb and left index fingers while other fingers show significant p value. All ten fingers had a positive correlation with mother's finger

Table 4.14.A: Siblings fingerprint patterns similarity

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL	%
Loop	43	43	55	28	61	36	40	42	36	66	450	**68.5**
Whorl	22	18	14	34	10	25	22	17	27	8	197	**30**
Arch	1	1	0	1	1	3	1	1	1	0	10	**1.5**
Total	**66**	**62**	**69**	**63**	**72**	**64**	**63**	**60**	**64**	**74**	**657**	**100**
%	**66**	**62**	**69**	**63**	**72**	**64**	**63**	**60**	**64**	**74**	**65.7**	**100**

Sibling groups shows similar fingerprint pattern in 657 fingers, 450 as matching loop patterns, 197 as whorl, and 10 arch pattern types and the percent of similarity was 65.7% with higher similarity in the left and right little fingers.

Table 4.14.B: Similarity correlation between sibling 1 and sibling 2

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	.353	.000
Pair 2	R index & R index	100	.217	.030
Pair 3	R middle & R middle	100	.152	.130
Pair 4	R ring & R ring	100	.226	.024
Pair 5	R little & R little	100	.249	.012
Pair 6	L thump & L thump	100	.218	.030
Pair 7	L index & L index	100	.205	.041
Pair 8	L middle & L middle	100	.093	.357
Pair 9	L ring & L ring	100	.226	.024
Pair 10	L little & L little	100	.195	.052

Correlation between siblings fingerprint pattern types show significant p value except in right and left middle finger with positive correlation in all fingers.

Table 4.15.A: Non-Siblings fingerprint patterns similarity

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	33	32	47	20	58	28	28	37	26	61	**370**
Whorl	15	9	5	25	6	14	9	7	17	3	**110**
Arch	0	0	0	0	0	0	0	0	0	0	**0**
Total	**48**	**41**	**52**	**45**	**64**	**42**	**37**	**44**	**43**	**64**	**480**
%	**48**	**41**	**52**	**45**	**64**	**42**	**37**	**44**	**43**	**64**	**48**

Non-Sibling groups shows similar fingerprint pattern in 480 fingers, 370 as matching loop patterns, 110 as whorl, and 0 arch pattern types and the percent of similarity was 48% with higher similarity in the left and right little fingers.

Table 4.15.B: Similarity correlation between non-siblings

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	-.083-	.414
Pair 2	R index & R index	100	-.203-	.043
Pair 3	R middle & R middle	100	-.077-	.449
Pair 4	R ring & R ring	100	-.047-	.640
Pair 5	R little & R little	100	.092	.365
Pair 6	L thump & L thump	100	-.061-	.544
Pair 7	L index & L index	100	-.106-	.292
Pair 8	L middle & L middle	100	.042	.675
Pair 9	L ring & L ring	100	-.161-	.109
Pair 10	L little & L little	100	-.088-	.382

Significant p value found in the right index only. Furthermore, non-sibling show negative correlation in all fingers except right little and left middle fingers.

Table 4.16.A: Fathers and mothers fingerprint patterns similarity

FPP	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL	TOTAL
Loop	34	36	49	36	64	46	38	47	35	70	**455**
Whorl	11	14	7	18	8	15	14	9	24	5	**125**
Arch	0	0	1	0	1	0	0	0	0	2	**4**
Total	**45**	**50**	**57**	**54**	**73**	**61**	**52**	**56**	**59**	**77**	**584**
%	**45**	**50**	**57**	**54**	**73**	**61**	**52**	**56**	**59**	**77**	**58**

Fathers and mothers group shows similar fingerprint pattern in 584 fingers, 455 as matching loop patterns, 125 as whorl, and 4 arch pattern types and the percent of similarity was 58.4% with higher similarity in the left and right little fingers.

Table 4.16.B: Similarity correlation between father & mother

		N	Correlation	Sig.
Pair 1	R thumb & R thumb	100	-.014-	.890
Pair 2	R index & R index	100	.085	.399
Pair 3	R middle & R middle	100	-.070-	.486
Pair 4	R ring & R ring	100	-.014-	.889
Pair 5	R little & R little	100	.169	.092
Pair 6	L thump & L thump	100	.139	.168
Pair 7	L index & L index	100	.053	.602
Pair 8	L middle & L middle	100	-.120-	.233
Pair 9	L ring & L ring	100	.085	.402
Pair 10	L little & L little	100	.435	.000

There was no significant correlation in all fingers except in the left little finger, and negative correlation in right thumb, right middle and left middle fingers

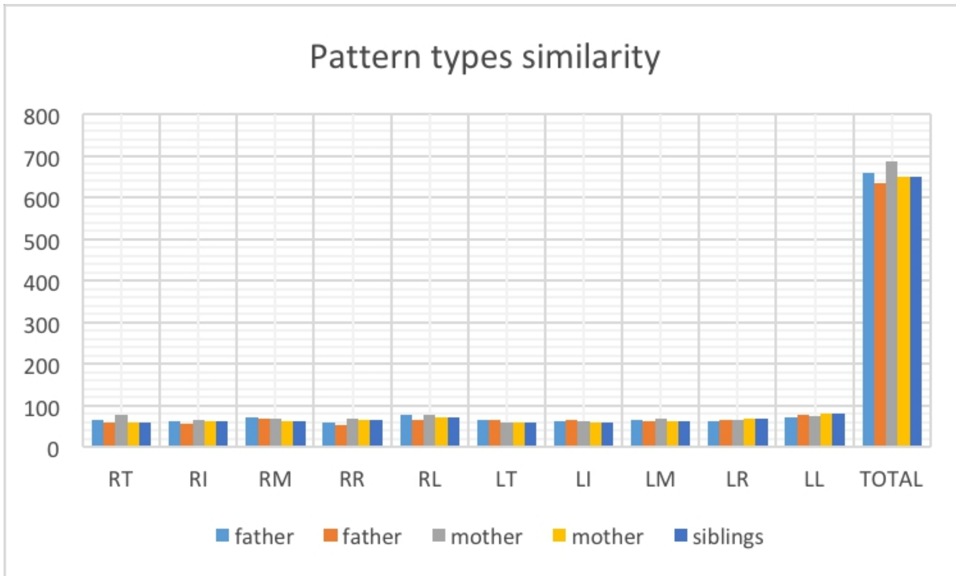


Figure 4.14: fingerprint pattern similarity in family

5.1. Discussion:

Aim of this study was to study the distribution of various patterns of fingerprints and correlate between patterns type of the siblings and their parents in Sudanese population live in Jabal Awlya. 100 families included in this study each family consisting of father, mother, and two of their offspring. The study population subdivided into four groups (fathers, mothers, sib1, and sib2), each group consisting of 100 subjects. All 4000 fingers of hands were classified and compared.

The study found that the most commonly occurring pattern type, which appear in all 4000 fingers of all groups was the loop pattern with a total of 2533 (63.3%) frequency followed by whorl with 1273 (31.82%) and the arch reported to be the lowest percentage 191 (4.77%).

Prevalence of fingerprint patterns as given by other authors (Oladipo and Akanigha 2005), (Mark 2009) and that obtained in the present study were compared. When we compare the previous data with the present study, we found that there is agreement between studies:

1) Prevalence of loop pattern is between 60 and 70% according to other authors, which corresponds to this study (63.3%).

2) Prevalence of whorls (31.82%) corresponds to that quoted by other authors (30 to 35%).

3) Prevalence of arch pattern in this study (4.77%) was lower to that quoted by other authors (5 to 15%).

The obtained result compared to fingerprint distributions for 32 countries around the world (www.handresearch.com/news/fingerprints-world-map-whorls-loops-arches.htm). The reported results around the world show that loops are seen in a majority (50%) of all fingers around the world. This tendency is sort of confirmed in 28 out of the 32 populations. Whorls are only sometimes more common than loops; only 5 out of 32 populations have more whorls than loops, but for whorls the percentage only in 4 populations higher than 50%, for: Ellice Island, New Guinea, New Zealand (Maoris) & Malaysia (www.handresearch.com/news/fingerprints-world-map-whorls-loops-arches.htm).

Out of total 2533 loops that observed in all groups the left little fingers with 321(80%) out of 400 fingers, and right little fingers with 306 (76.5%) occurrences, founds to be the highest frequencies. This agreed with Tanuj Kanchan, Saurabh Chattopadhyay (Kanchan and Chattopadhyay 2006) whom found that there was preponderance of loops on the little and middle finger. While the less frequencies reported in ring fingers (right 209 (52%), and left 219 (54.7%)).

Figure 1 Figure 5.1 Loop pattern

Out of total 1273 whorls that observed in all groups the right ring fingers with 178 (44.5%) out of 400 fingers and the left ring fingers with 171(42.7%) occurrences, were founds to be the highest frequencies. This agreed with Tanuj Kanchan, Saurabh Chattopadhyay (Kanchan and Chattopadhyay 2006) whom found that there was preponderance of whorls on the thumb and ring finger. While the less frequencies reported in little fingers (left 74(18.5%), and right 87(21.7)).

Figure 2 Figure 5.2: Whorl pattern

Out of total 191 arches that observed in all groups the left index fingers with 33(8%) out of 400 fingers and left middle finger with 31(7.7%) occurrences, founds to be the highest frequencies. This agreed in left index and disagreed in left middle with Tanuj Kanchan, Saurabh Chattopadhyay (Kanchan and Chattopadhyay 2006) whom found that there was preponderance of arches on the index finger in both hands. While the less frequencies reported in little fingers (left 5(1%), and right 7(1.7%)) (Table 4.3).

Figure 3 Figure 5.3: Arch pattern

On analyzing the distribution of fingerprint patterns in either sex, the mothers group with 681 (68%) loop had high percentage compared to fathers group with 626 (62.6%), among sib1 and sib2 out of 73 male the frequencies of loop pattern was 432 (59%) and out of 127 female 794 (62.5%) was loop pattern which found to be higher than male.

Fathers group shows high whorl pattern (325 (32%)) compared to mothers group with 274 (27.4%), within sibling groups (sib1 +sib2) male with 280 (38%) whorl pattern found to be higher than female with 394 (31%). Furthermore arch pattern was high in fathers group (47) than mothers group (44). While among sibling groups, out of 127 female 82 (6.4%) was arch pattern which found to be higher than male with 18 (2.4%) arch pattern out of 73 male.

Therefore, loops were the predominant pattern in both genders, followed by whorls. The less common pattern in both gender was arch. This found to be agreed with Nithin Mathew Sam et al (Sam, Rema et al. 2014) whom find out the same result in study of fingerprint patterns in South Indian population.

Hence, the study find that the distribution of fingerprint patterns in male and female subjects is similar to that observed in the general sample population with loop and arch patterns higher in female, while whorl pattern higher in male. This found to be agreed with Desai Bhavana, Jaiswal Ruchi et al (Bhavana, Ruchi et al. 2013). And agreed with Dr. Prateek Rastogi, Ms. Keerthi R Pillai (Rastogi and Pillai 2010); whom done a study of fingerprints in relation to gender and blood group and find that males have a higher incidence of whorls and females have a higher incidence of loops. In Australian Aborigines in the Northern Territory of Australia (Cho 2000), Ching Cho found out the same result with difference in that the common pattern is whorl and the second frequent is loop.

In addition, the study shows that the right finger and the same finger on left hand of the same subject do not 100% show the same pattern types.

However, there is strong positive relation between right and left fingers with highly significant P value (0.00) in all fingers. - Fathers and sib2 shows high correlation in thumb 0.720 and 0.702 respectively, mothers and sib1 groups shows high correlation in little fingers 0.833and 0.654 respectively. While the lower positive correlation found in the index fingers of fathers group (.338) and the little fingers of sib2 group (.313). This agreed with Tanuj Kanchan, Saurabh Chattopadhyay (Kanchan and Chattopadhyay 2006) whom found that the distribution of fingerprint patterns was similar on both hands for both sexes - With highest frequency of loop pattern in little fingers, whorl pattern in ring fingers and arch pattern in left index and left middle fingers.

The common fingerprint pattern of the ten fingers in this study was loop pattern. Which is the similar to that in Tanzania, Kenya, Nigeria, Costa Rica, England, Boland, France and Netherlands. Other countries have deferent sequences in Malaysia for example the common pattern is whorl in all fingers (www.handresearch.com/news/fingerprints-world-map-whorls-loops-arches.htm), in Yemen LWLWLLWLWL (from right thumb to left little fingers) (fingerprint world map).

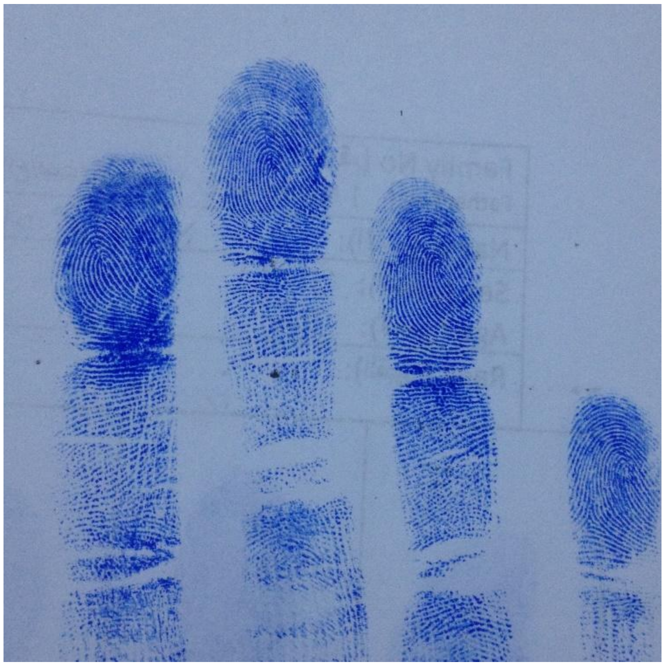


Figure 4 Figure 5.4: Right medial fingers

Figure 5 Figure 5.5: Left medial fingers

Only three fingers reported as unprinted fingers, two amputated fingers in fathers group and one in mothers group with undistinguished type lines due to recent burn.

On the similarity of fingerprint pattern between offspring and their parents. The percentage of matching fingers pattern type with father or mother were calculated and aggregated. Finally, the p value and correlation between offspring fingerprint pattern types and their parents were calculated. We found that the similarity between offspring and their parents had a significant p value in some fingers and non-significant in others:

- Sibling1 group shows similar fingerprint pattern with fathers in 659 fingers 65.9% out of 1000, with higher similarity in the right and left little fingers, 468 as matching loop patterns, 187 as whorl, and 4 arch pattern types. The non-significant p value found in right index, left index, left middle and left little fingers while other fingers show significant p value. All ten fingers had a positive correlation with father's finger.
- Sibling 1 groups shows similar fingerprint pattern with mother in 685 fingers 68.9% out of 1000, with higher similarity in the right thumb and right little fingers, 500 as matching loop patterns, 183 as whorl, and 2 arch pattern types. The non-significant p value found in right middle, left thumb, left index, left middle and left little fingers while other fingers show significant p value. All ten fingers had a positive correlation with mother's finger.
- Sibling 2 group shows similar fingerprint pattern with father in 634 fingers 63.4% out of 1000, with higher similarity in the left little fingers, 433 as matching loop patterns, 189 as whorl, and 12 arch pattern types. Left index, left ring and left little fingers had a significant p value while other fingers were non-significant. Right ring

show negative correlation and other fingers show positive correlation with father fingers.

- Sibling 2 group shows similar fingerprint pattern with mother in 649 fingers 64.9% out of 1000, with higher similarity in the left and right little fingers, 471 as matching loop patterns, 166 as whorl, and 12 arch pattern types (table 4.13.C). The non-significant p value found in right little, left thumb and left index fingers while other fingers show significant p value. All ten fingers had a positive correlation with mother's finger.

When we compare the relation between fingers pattern type of the offspring and their parents with the relation between patterns type of mothers and fathers groups the results indicate that:

Fathers and mothers groups show similar fingerprint pattern in 584 fingers, 455 as matching loop patterns, 125 as whorl, and 4 arch pattern types and the percent of similarity was 58.4% with higher similarity in the left and right little fingers. There was no significant correlation in all fingers except in the left little finger, and negative correlation in right thumb, right middle and left middle fingers. Therefore, the present results showed that:

- Fingerprint pattern do not 100% match one of parents in all populations; nevertheless, there is similarity between offspring and their parents.
- The loop pattern in offspring fingers had the highest matching tendency to his/her parent. Furthermore, the whorl pattern of offspring show positive similarity correlation with their parents and this agree with Herman M. Slatis et al, whom at 1976 found that as the proportion of whorls among the parents increases, the proportion of

children with whorls also increases. Although arch pattern is rare, when it present show less similarity between sibling and parents, which affect the general p value, we observed that when exclude arch patterns the significance of p value increased. Generally fingerprint pattern types similar to one of parents more than non-related people according to this study and this agree with Jacob B. Adler (2003) who found that (there is indeed a relationship between fingerprints of people in a family. All of the groups of related people had more features in common than non-related people).

- Although the percent of female was high 72% in sib1 group and 55% in sib2 group analysis of male and female similarity with parents shows that the gender had no clear effect in the percent of similarity.

On the similarity of pattern types between siblings:

Sibling groups shows similar fingerprint pattern in 657 fingers, 450 as matching loop patterns, 197 as whorl, and 10 arch pattern types and the percent of similarity was 65.7% with higher similarity in the left and right little fingers.

The study shows that there is similarity between siblings fingerprint pattern types with highly significant p value except in right and left middle finger which found to be had 69% of the right middle fingers pattern types similar in siblings and 60% of the left middle finger. The not significant asymmetry in the middle fingers due to present of arch pattern, which found to be, had a very low similarity proportion in all population.

To make evidence to our results we compare similarity between sibling fingerprint patterns with the similarity between non-siblings fingerprint pattern. We found that Non-Sibling groups shows similar fingerprint pattern in 480 fingers, 370 as matching loop patterns, 110 as whorl, and 0 arch pattern types and the percent of similarity was 48% with no significant in nine fingers and the only significant p value found in the right index. Furthermore siblings group show positive correlation in all fingers while non-sibling show negative correlation in all fingers except right little and left middle fingers only.

The results confirm that the similarity between siblings is highly significant than that between offspring and their parents and that between non-siblings. Carly R. Dion, on 2012 found that (Fingerprint patterns do show similarity between siblings. Fingerprints may be unique, but fingerprint patterns will often lie within the same category as a sibling).

The results of this study should be followed by other studies to find out more correlation within family fingerprint like inheritance of fingerprint pattern type, relation between pattern types and other fingerprint details (delta, type line, …etc.), and twins fingerprint patterns similarity.

5.2. Conclusion

On the base of this study, we conclude that:

- The most common fingerprint pattern is the loop followed by whorl, while arch found to be the least finger print pattern.
- Loop pattern and arch pattern higher in female than male, while whorl pattern higher in male.
- Loop pattern is the predominant fingerprint pattern. Hence, it has a highest similarity percent in family.
- Offspring of parents with whorl pattern in one of their fingers usually have whorl in the same finger.
- Arch pattern do not match parents.
- There is strong correlation between siblings more than unrelated subjects.

5.3. Recommendation:

- The information gained from this study could help police to determine criminal's fingerprints by looking at some of their family member's. It could also help orphans find their biological parents.
- This study should be done again at the same family in correlation with genetic factors.
- Further studies should be done investigating more fingerprint samples concentrating on twins.
- Fingerprints is unique, further studies should be concentrating on the detail of fingerprint like type lines, delta, dot …etc.

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6.2. Appendix

Family No (الرقم): ( ) Father (اب) ( ) Mother (ام) ( ) Sibling (اخ/اخت) ( )	لون العيون:1. اسود ( ) 2. بني( ) 3. عسلي( ) 4. اخري حدد ....
Name (الاسم):	شحمة الأذن: 1. ملتحمة ( ) 2. غير ملتحمة ( )
Sex (الجنس):	**LEAVE BLANK** **Classification :** **هذه البصمات للبحث العلمى فقط.**
Race (القبيلة):	

Fingerprint card No (   ) استمارة جمع البصمات رقم

1. R. THUMB	2. R. INDEX	3. R. MIDDLE	4. R. RING	5. R. LITTLE
6. L. THUMB	7. L. INDEX	8. L. MIDDLE	9. L. RING	10. L. LITTLE

LEFT FOUR FINGER AND PALM	RIGHT FOUR FINGER AND PALM

1. السكن:..
2. المهنة:..
3. الطول:..
4. الوزن:..
5. طول الشبر (من الابهام الي البنصر):...
6. طول الزند:..
7. طول الوجه (من الذقن الي بداية فروة الراس):...
8. عرض الخصر:...
9. طول القدم (الحذاء):...
10. طول الطرف الاسفل (الرجل):..
11. نمط اصابع القدم: أ. اطولها الاصبع الكبير ( ) ب. اطولها الاصبع الثاني ( )
12. تعرق اليدين والقدمين بصورة ملحوظة: 1. نعم ( ) 2. لا ( )
13. التاريخ المرضي:
    أ. السكري: 1. نعم ( ) 2. لا ( )
    ب. الضغط: 1. نعم ( ) 2. لا ( )
    ت. الجزام: 1. نعم ( ) 2. لا ( )
    ث. البرص: 1. نعم ( ) 2. لا ( )
    ج. اكزيما: 1. نعم ( ) 2. لا ( )
    ح. بتر: 1. نعم ( ) 2. لا ( ) حدد ....
    خ. الصداع النصفي (الشقيقة): : 1. نعم ( ) 2. لا ( ) حدد النصف (الشق):........
    د. امراض خلقية: : 1. نعم ( ) 2. لا ( ) حدد..
    ذ. كسر في الفخذ: 1. نعم ( ) 2. لا ( ) كسور اخري حدد...........................
    ر. مشاكل السلسلة الفقارية (قضروف ، خشونة ..الخ) : 1. نعم ( ) 2. لا ( ) حدد..........................
    ز. امراض جلدية او عظمية اخري حدد :
    ....

انا .... بعد الاطلاع علي اهداف البحث أوافق ان تستخدم هذه البيانات من اجل البحث العلمي ولا امانع مشاركة نتيجة الدراسة ونشرها.