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EFFECT OF WATER SUBMERGENCE ON RIDGE CHARACTERISTICS AND PORE MORPHOLOGY FOR FINGERPRINTS

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ABSTRACT

Fingerprints are created by the elevated ridges on the fingertips, which leave impressions on things. It is essential to a person's identification because of how special it is. The level 1 feature is an overall ridge flow pattern. Ridge characteristics, also known as minutiae, make up the level 2 features of a fingerprint and are the particulars of each ridge. Level 3 features of a fingerprint include pore morphology and characteristics as well as fingerprint ridge density (FPRD), which are precise and useful for identifying a specific person. All of these characteristics aid in identification when the epidermis is broken by any kind of damage, such as burns or prolonged submersion in water. Finger phalanges can be difficult to identify and subject to forensic analysis when submerged in water for an extended period of time. This study involved subjects between the ages of 21 and 35 and was conducted among the Indian population. The left hand's thumbprints were recorded using kores ink over fingerprint slips both before and after being submerged in water for various amounts of time. The goal of this research is to examine how ridge characteristics and pore morphology are affected by water submersion for fingerprint analysis. The number of tiny particles found in post-submergence prints was found to be decreasing in a small number of subjects when compared to pre-submergence prints, and round, closed, medium-sized pores were most frequently found. Additionally, it was discovered that pre-and post-submergence fingerprints had a significant mean difference in ridge density. The results of the current study will be extremely important in drowning cases where fingerprints are anticipated to be used for personal identification.

INTRODUCTION

The well-established and well-known method of identifying humans is their fingerprints. The field of dactylography had long been thought of as a panacea for individualization, particularly in forensic investigations.[2] Human fingerprints are exceptional as permanent markers of human identification because they are distinct, intricate, challenging to alter, and long-lasting. For more than a century, fingerprints have been the most reliable method for personal identification in the forensic field. As a result, it helps law enforcement greatly.[1] Fingerprints are imprints left behind on surfaces by the papillary ridges on the tips of the fingers. Fingerprints are made when sweat and oil from hands come into contact with a surface and leave a mark. They are frequently used to identify criminals as well as the sick or dead, as in the case of natural disasters. Frictional ridges, which are numerous in number, make up a fingerprint. Each ridge has pores that are connected to sweat glands under the skin.[6] Normally and even when the epidermis is destroyed by damage of any kind, such as burns or prolonged submersion in water, these ridges act as a tool for identification.

Fingerprint analysis is challenging in drowning cases because the victims' fingertips wrinkle, making it challenging to examine small details. In order to analyze fingerprints, this study aims to determine how ridge characteristics and pore morphology are affected by water submersion. This study primarily focuses on the variations in fingerprint features seen in pre-and post- submergence prints.

DEVELOPNMENT OF FINGERPRINTS

The field of personal identification using fingerprints has been established by the development of dermatoglyphics as a scientific discipline. A fingerprint is a term used to describe friction ridge skin (FRS), which is made up of ridges and grooves. The dermis, which is the innermost layer of the frictional ridged skin, and the epidermis, which is the outermost layer, make up the frictional ridged skin.

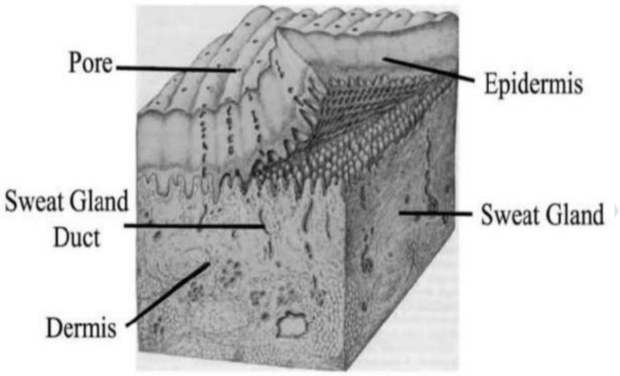


Figure 1: A three-dimensional representation of the structure of ridged skin.

The epidermis develops ridges to increase friction between the volar and contact surface.[6] The characteristics of the friction ridges are formed while a person is developing their fingerprints in the womb. Among the genetic and environmental factors that affect these traits is the growth of the volar pads that surround each fingertip, the movement of fluids inside the womb, and the location and size of the foetus. Replication is uncommon due to the large number of variables that affect friction ridge features.[39] In contrast to a female, a typical young male has 23.4 ridges per centimeter.[6] Friction ridges are thought to be composed of tiny "ridge units," each with a pore, the number and placement of which are chosen at random. As a result, each individual's ridge unit is distinct in terms of its size, alignment, shape, and fusion with other ridge units.[6] Between the fifth and sixth weeks of pregnancy, fingerprint patterns start to emerge and fully develop by the twenty-first week. Around week fourteen of pregnancy, sweat glands start to develop, and by week twenty-four, they have fully developed morphology.[7] Pores travel through the epidermis and into the dermis. Although the first sweat glands begin to develop in the fifth month of pregnancy, epidermal ridges don't start to develop until the sixth. Accordingly, the pores on the ridges are stabilized before the epidermis and dermis form, and they remain immutable after the ridges have formed.[28] As seen in the figure below, the perspiration activity of a pore in a fingerprint image can be seen as open or closed.

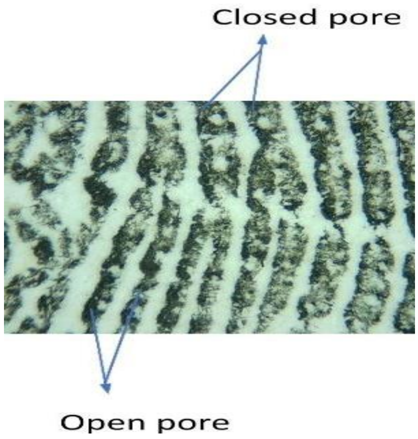


Figure 2: Closed and open sweat pores viewed under a stereomicroscope with standard 40x magnification.

In contrast to a closed pore, which is completely encircled by a ridge, an open pore communicates within the valley that lies between two ridges. A pore is a sweat duct aperture that develops from sweat glands in the subcutaneous layer of the skin. [39]
Identical twins have the same DNA but distinct fingerprints because of how the embryo develops in the womb. The unique folds created by the digit's contact with the uterine wall are what give rise to fingerprints. Since each finger on each hand develops in its own microenvironment, fingerprints are phenotypic traits unique to each person.[14]

FINGERPRINT FEATURES

Fingerprint features are divided into three categories: level-1, level-2, and level-3 features.[6]

Level-1 characteristics are used to illustrate the ridge-flow pattern and overall morphological data. Level-2 features, such as ridge ending, bifurcation, enclosures, trifurcations, and islands are represented by level-2 traits. Level-3 traits are provided by sweat pores, their morphology, breaks, creases, scars, and other permanent details visible in fingerprints. These traits are used to categorize fingerprints into a loop, whorl, and arch[24]. All three tiers of fingerprint features fall under this category, and they are the most discriminating.[6]

LEVEL 1 FEATURES:

This includes the way the ridges on a fingerprint flow in a pattern. Arch, whorl, and loop are the three main pattern types (central pocket loop and double loop - twinned loop and lateral pocket loop). Accidental patterns are those that don't fit into any of the categories listed above. When combined with level 2 and 3 features, the fingerprint recognition system can become more robust and secure. These pattern elements by themselves are insufficient to uniquely identify or recognize a person. About 5% of fingerprint patterns that are encountered have arches, which are divided into two subgroups: plain arch and tented arch. Of the three general patterns, the loop patterns—ulnar loop and radial loop—are the most prevalent. Ulnar loops are referred to when the little finger is in the direction that the loop opens. It is a radial loop if the direction of the loop's opening is toward the thumb. Whorls are the second most typical of the three basic patterns. There are three subgroups within it: plain whorl, central pocket loop, and double loop. The twinned loop and lateral pocket loop are further divisions of the double loop. Accidental patterns are those whose existence is solely due to chance or accident and do not fit into any of the general patterns previously mentioned.

LEVEL 2 FEATURES:

Minutiae, also known as ridge characteristics are little details or infrequent fractures or disruptions on ridges, such as ridge endings, bifurcation, trifurcation, enclosures, islands, and so on There are 40 to 100 minutiae in a good-quality photograph.[15] Sir Francis Galton (1822-1922), who was the first to notice the features and stability of ridge details, is also known as "Galton details."[16], [42]. The minutiae are useful for distinguishing fingerprints because they can describe invariant and discriminatory information.

LEVEL 3 FEATURES:

This includes the specifics found on the fingerprint, such as ridge density, pores, creases, scars, breaks, and breaks. This study will concentrate on the fingerprint's sweat pore characteristics and ridge density, as well as any changes brought on by submersion in water or artificial wrinkle induction.

Poroscopy, a technique for identifying people by comparing sweat pores on palmer and plantar surfaces, was developed by the French criminologist Dr. Edmond Locard. These pores, which resemble tiny holes in sweat gland ducts, are used to establish identity.

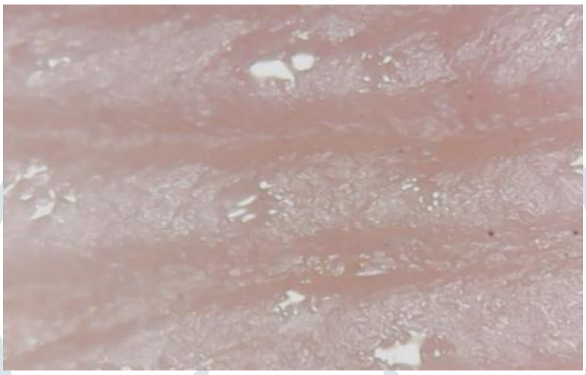


Figure 3: Sweat pores viewed under a digital microscope

Poroscopy (size, shape, type, and relative position) is the study of the tiniest anatomical structures on finger ridges and is used as a tool for personal identification. [11] It has proven to be a very helpful instrument in forensic science. According to a 2012 study by Preethi, women have more pores than men do. A pore is a sweat duct opening that originates from a sweat gland and is located in the subcutaneous layer. Males had 8/25 mm2 of pores compared to females' 9/25 mm2 of pores. [5] While in another study by Nagesh (2010) the average number of pores/cm of ridge found was 8.40 in males and 8.83 in females.[30] Matching 20 to 40 pores in two prints can establish one's identity. Two scenarios allow for the use of pore referencing.

SWEAT PORE CHARACTERISTICS

Oval, squarish, rectangular, triangular, elliptical, pentagonal, rounded, and rhomboid are just a few of the different shapes and sizes of pores.[5] Pores can appear as single, double, or chained structures (grouping of pores). Pores can range in size from tiny too large. Both the centre and the edge of the ridge may have pores. Per cent of ridge length, there may be 8–11 pores.[4] You can have open or closed pores. An open pore cuts the canyon in half between two ridges, whereas a closed pore is completely encircled by the ridge [5] The separation or space between the pores can be calculated using the number of pores per unit area or per cm of ridge length and how they are arranged.[8] It falls under the headings of:

When pores are very closely spaced from one another and more than 12 pores are found on a ridge measuring 1 cm in length, the pores are said to have a close interspacing. When there are 8 to 11 pores present on a chosen 1 cm length of ridge and the distance between the pores is greater, the pores are said to have distant interspacing. Pores in groups with close interspacing occur when there are two or more groups of pores per square centimeter. Chain-like formation of the pores: This type of pore is defined as having no space between the pores and being connected to one another in a chain-like formation Even though these situations may make up less than 1% of all fingerprint identifications performed each year, it is a reliable method of identifying people in some situations because pores change in type, shape, position, and size as

people age.[30]
The quantity of ridges in a given area is known as fingerprint ridge density (FPRD). The number of ridges in a fingerprint's unit area is another way to express it. Women frequently have greater ridge density than men, according to a Thakar study from 2018 that supports these findings13. In this particular study, men had 12.32 ridges in 25 mm2, while women had 13.94 ridges. Ridge thickness and furrows are the two primary factors that affect ridge density.[48]

FACTORS AFFECTING PORE MORPHOLOGY:

A number of factors can influence the morphology of pores. Human factors include things like the amount of pressure used to deposit an inked impression, any cuts or abrasions, dirt on the skin surface of the friction ridge, the person's mental state at the time the impression was given, temperature, humidity, and perspiration level, to name a few. Pore diameters can be changed by external factors like the type of surface used to make the impression and the caliber of the ink. Growth, amputation, and scarring are examples of biological variables.[38]

WRINKLING AND ITS PHYSICAL EFFECT ON FINGERS

Skin wrinkles are thought to be an adaptive reaction to an evolutionary process that occurs when someone is submerged in water. It's unknown exactly how wrinkles form.[34] It's possible that as people age, changes in the structure, size, organization, and qualities of their skin manifest. The fingers and toes wrinkle when exposed to water, which was initially attributed to local osmotic mechanisms. Wrinkling brought on by water immersion is linked to increased skin rigidity, as well as weakening and loss of echogenicity in the uppermost dermis. [33]
A study by Surya et al. (2020) discovered that females require more time to develop wrinkling than males. Water aging is a temporary effect of exposure to water that causes wrinkles.41Previous research has shown that the presence of wrinkles depends on factors like temperature, hardness, pH, and other variables. It has been demonstrated that menopausal hypoestrogenism speeds up age-related degeneration, resulting in thinner skin and more wrinkles with deeper lines. [44]
The position of some fingerprint features, such as ridge details, delta, core, and pores, in wrinkled fingerprints may be altered, resulting in a reduction in accurate matching. This is because the skin's surface is non-isometrically distorted, making it more difficult to recognize wrinkled fingerprints than dry ones.[24] How long a finger is left in water or other liquids influences how many wrinkles there are on wrinkled fingertips. In time, wrinkles change from
the middle of the fingertip to the sides and top portions. Different fingers are affected by wrinkles differently; it has been found that the thumb is less affected by wrinkles than the other fingers in terms of recognition.[25] According to a study, using warm water at 40°C with a basic pH of 8.1 causes finger wrinkles.[43]
One of the most important functions of the sympathetic system in the limbs is maintaining vascular tone. Due to vasoconstriction in the digital arteries, which results in finger wrinkles after immersion in water, the peripheral sympathetic function is evaluated. Diabetics and parkinsonism (wrinkling appears to decrease in such cases) are the two medical conditions most frequently linked to abnormal finger wrinkling test results. [22]

PHYSICAL EFFECTS OF WRINKLING ON THE FINGERS

U-shaped artifacts due to clumping of skin.
Pre-existing cuts become more prominent

Ridges become thicker
Disassociating of minutiae [25]

RESEARCH HYPOTHESIS

Null hypothesis: There is no effect of water submergence on ridge characteristics and pore morphology of fingerprints
Alternate hypothesis: There is an effect of water submergence on ridge characteristics and pore morphology of fingerprints
Type of Study: The proposed study follows Experimental Research Design.
Number of Samples: 100
Materials Required: Kore's ink, roller, and slab, fingerprint slips, a container with water, magnifying hand lens, stereomicroscope, and digital microscope.

SAMPLING

Twenty-five subjects (11 males and 14 females) were selected randomly from the age between 21 and 35 years. The age group was not chosen but is as per the availability of donors and their voluntary participation. The objective of the study was explained to the subjects before starting the test and written consent was taken. Subjects having any injury or ailment to the fingertips that could modify the fingerprint pattern (lacerations, scars, or any disease) were excluded from the study. Subjects were informed before not to use any kind of creams or lotions on their hand on the day of testing. Fingerprints were taken using kore's ink on fingerprint slips in the designated area. Pre-submergence prints were taken before the test. Rolled and flat inked fingerprints were collected from the left hand of the subjects. During the test, the left hand was immersed in a container filled with water (tap water) maintained at 40 0C. The prints were then taken after 15 minutes, 1 hour, and 2 hours of immersion. Thus, four samples were collected from each subject, treating each sample as a separate identity to be recognized; it becomes a total of 100 samples to be analyzed in the current study. Out of all the fingers, the thumb was selected for the study because it is the most motile of all fingers, and it is more likely to leave imprints.

INSTRUMENTATION

All samples were studied using a Stereomicroscope for examination of sweat pores. The stereomicroscope is an optical microscope made for low magnification sample examination; it frequently uses light reflected off an object's surface rather than being transmitted through it. The equipment uses two distinct optical channels, two objectives, and eyepieces. A digital microscope was also used to view the sweat pore on the fingertips.

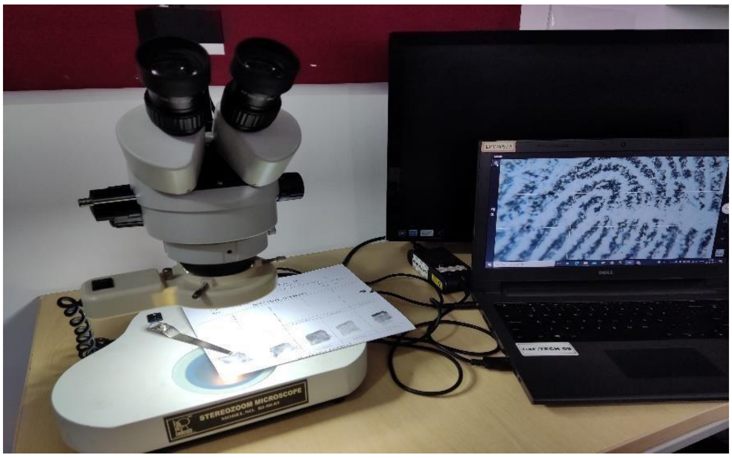


Figure 4: Pore characteristics examination using stereo microscope

ANALYSIS

The general ridge flow patterns of the selected finger were noted down. The thumbprints taken were then examined for ridge characteristics. Each pre-submergence print was marked with a minimum of 8 minutiae and then it was compared with the same subject's post- submergence prints and the number of minutiae identified was noted down. Since 8 minutiae are the minimum requirement for a perfect match of two prints, that's why 8 minutiae were taken as minimum criteria.

The post submergence prints and pre-submergence prints taken were then examined under a stereo microscope at 40x magnification to study the effect of water submergence on pore morphology. A ridge length of 0.5 cm was selected in the study to examine the pore features. The pore features like shape (round, oval, square, rhomboid), size (large, medium, small), type (closed, open [1 side open, 2 sides open]), position (Centre, periphery), interspacing (close, distant, groups, chains) were examined in this study.

For calculation of thumbprint ridge density, a format similar as shown in the figure given below was created on a clean glass slide

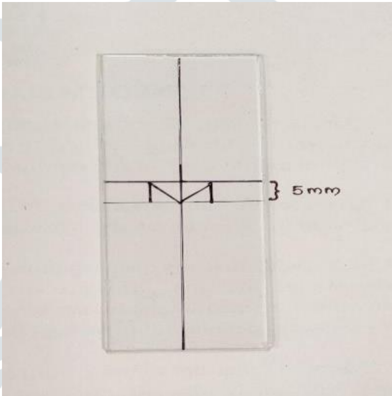


Figure 5: The format drawn on glass slide

At first, two straight lines bisecting each other were drawn on the glass slide. The intersecting point was then placed at the core of the print. Measuring 5 mm above it, draw another line. Two squares of each measured 25mm2 were drawn on both sides of the bisecting point which is placed above the core of the print. This was the area chosen for the analysis of ridge density. Two diagonals were drawn inside both squares as shown in fig and the ridges intersecting the diagonals were counted and tabulated for the study. While counting the ridges, the glass slide was superimposed on the print. In the case of whorls and loops, the lower intersection lies on the core of the print while in arch patterns the lowest intersection lies on the approximate center of the print (figure 8, 9, & 10). In twinned loops, the descending loop was considered. The ridges were then counted from one corner of the square to the diagonally opposite corner. If the drawn diagonal passes through the point of divergence of two ridges (bifurcation) then it was counted as two ridges. A lake or an enclosure was counted as two ridges. Dots were excluded.

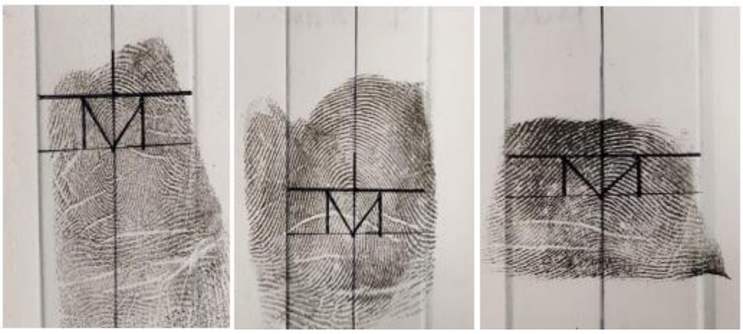


Figure 6,7, & 8: plain whorl, ulnar loop, and arch pattern with area an of (2 of 25 mm2) used for counting left thumbprint ridge densities at the LoC and RoC.

SULTS AND DISCUSSION

The level 1 features or the ridge flow patterns of the left thumb of the subjects are depicted in Table 1. It was found that the majority of prints were ulnar loops followed by twinned loops, plain whorl, and arch pattern and post-submergence prints of the subjects. It was found that in most of the pre- submergence and post submergence prints minimum of 8 characters were identified. Only in very few post-submergence prints, the number of minutiae identified was less in number as compared to the other prints. This was due to the creases formed due to water-induced wrinkling.

SUBJECT	RIDGE- FLOW PATTERN IDENTIFIED ON THE LEFT THUMB
1	TWINNED LOOP
2	ULNAR LOOP
3	PLAIN WHORL
4	PLAIN ARCH
5	ULNAR LOOP
6	TWINNED LOOP
7	ULNAR LOOP
8	ULNAR LOOP
9	TWINNED LOOP
10	ULNAR LOOP
11	ULNAR LOOP
12	PLAIN WHORL
13	ULNAR LOOP
14	PLAIN WHORL
15	ULNAR LOOP
16	ULNAR LOOP
17	TWINNED LOOP
18	TWINNED LOOP
19	TWINNED LOOP
20	ULNAR LOOP
21	ULNAR LOOP
22	TWINNED LOOP
23	PLAIN WHORL
24	TWINNED LOOP
25	ULNAR LOOP

SUBJECT		NUMBER OF RIDGE CHARACTERISTICS IDENTIFIED ON THE LEFT THUMB		
PRE-SUBMERGENCE PRINTS		POST-SUBMERGENCE PRINTS		
SNO		15 MINUTES	1 HOUR	2 HOURS
1	8	8	8	8
2	8	8	8	8
3	8	8	8	8
4	8	8	8	8
5	8	8	8	8
6	8	8	8	8
7	8	8	8	8
8	8	8	8	7
9	8	8	8	8
10	8	8	8	8

Table 1: Ridge flow pattern identified on the left thumb of the subjects & Table 2 shows the number of ridge characteristics or minutiae identified in pre-submergence

11	8	8	8	8
12	8	8	8	8
13	8	8	8	7
14	8	8	8	8
15	8	8	8	8
16	8	8	8	8
17	8	8	8	8
18	8	8	7	6
19	8	8	8	8
20	8	8	8	8
21	8	8	8	8
22	8	8	8	7
23	8	8	8	8
24	8	8	8	8
25	8	8	8	8

Table 2: Number of ridge characteristics identified on the left thumb in pre-submergence and post-submergence prints

Table 3 shows the pore characteristics observed in pre-submergence and post-submergence prints. The main features observed in a selected area of 0.5 cm were pore shape, size, type, position, and spacing. It was found that the majority of the pores in the selected area were round in shape, medium-sized, either closed or 1 side open pores, situated in the centre of the ridge with close interspacing.

SUBJECTS	PORE CHARACTERISTICS OBSERVED IN 0.5 CM RIDGE LENGTH				
	SHAPE	SIZE	TYPE	POSITION	INTERSPACING
1	Round, oval	Medium, small	Closed, open(1s)	Central	Close
2	Round	Medium	Closed, open(1s)	Central	Close, Chain
3	Round	Medium, small	Closed	Central	Groups with close
4	Round	Medium, small	Closed, open (1s)	Peripheral	Groups with close
5	Round	Medium	Closed Open (1s, 2s)	Central	Close
6	Round	Medium	Closed	Central	Close
7	Round, oval	Small	Closed Open(1s)	Central	Close, chain
8	Round	Medium	Closed, Open (1s,2s)	Central	Distant

9	Round, oval	Medium, small	Closed, Open (1s)	Central, peripheral	Close
10	Round, Oval	Medium	Closed, Open (1s,2s)	Central	Close, chain
11	Round, oval	Small	Closed, Open(1s)	Central, peripheral	Close, chain
12	Round, oval	Medium	Closed, Open(1s)	Central	Close, chain
13	Oval	Medium	Closed, Open(1s)	Peripheral	Close
14	Round	Medium	Closed, Open(1s)	Central	Groups with close
15	Round	Medium	Closed	Central	Distant
16	Oval	Medium, small	Open (1s)	Peripheral	Groups with close spacing, chain
17	Round, oval	Medium, small	Open (1s)	Central, peripheral	Groups with close spacing
18	Round	Small	Closed Open (1s)	Central	Groups with close spacing, chain
19	Oval	Medium	Open (1s)	Central	Distant
20	Round	Small	Closed Open (1s)	Central peripheral	Groups with close spacing, chain
21	Round	Small	Closed Open (1s,2s)	Central peripheral	Groups with close spacing, chain
22	Round Oval	Medium	Closed Open (1s)	central	Groups with close spacing
23	Round	Medium	Closed Open (1s)	central	Groups with close spacing, chain
24	Round Oval	Medium	Open (1s,2s)	central	Close, chain
25	Round	Medium	Open (1s,2s)	Central periphery	Close, chain

Table 3 Pore characteristics observed in the left thumbprints.

S.no	Pre submergence prints		Post submergence prints					
	LoC (Left of centre)	RoC (Right of centre)	15 minutes		1 hour		2 hours	
			Loc 1	Roc 1	Loc 2	Roc 2	Loc 3	Roc 3
1	15	17	15	17	14	15	14	14
2	17	16	15	16	15	15	15	14
3	14	16	12	15	12	14	11	13
4	12	12	12	11	11	11	10	11

5	13	18	13	17	12	16	12	16
6	14	18	13	18	13	16	13	15
7	14	17	13	16	13	16	12	16
8	14	17	13	17	13	15	12	15
9	16	17	15	17	13	16	13	15
10	13	17	13	16	12	16	11	15
11	14	18	13	17	13	16	12	16
12	14	18	14	17	14	16	12	15
13	13	16	13	15	13	14	12	14
14	15	19	13	19	13	17	13	16
15	11	15	10	15	10	13	9	13
16	15	18	14	17	14	16	13	16
17	14	15	13	14	12	12	10	11
18	14	17	13	16	13	15	13	15
19	18	17	17	16	15	16	13	16
20	14	15	13	15	13	14	12	14
21	15	14	15	13	14	13	14	13
22	11	15	11	14	10	14	10	13
23	15	16	15	14	14	13	13	12
24	15	16	15	15	14	14	14	13
25	13	15	13	14	12	14	12	13

Table 4: Ridge density in pre-submergence and post-submergence prints of LoC and RoC of the selected square of 25mm2 each.

Statistical Analysis

In pre-submergence prints the normal ridge density ranged from 11- 18 ridges per 25mm2 at LoC with mean ridge density of 14.9 and 12- 19 ridges per 25mm2 at RoC with mean ridge density 15.5. In post-submergence print within the interval of 15 minutes, the ridge density ranged from 10-17 ridges per 25mm2 at LoC with mean ridge density of 15.5 and 11-17 ridges per 25mm2 at RoC with mean ridge density of 14. In post-submergence print within the interval of 1 hour, the ridge density ranged from10-15 ridges per 25mm2 at LoC with a mean ridge density of 12.5 and 11-17 ridges per 25mm2 at RoC with a mean ridge density of 14. In the post-submergence prints within the interval of 2 hours, the ridge density ranged from 9-15 ridges per 25mm2 at LoC with a mean ridge density of 12 and 11-16 ridges per 25mm2 at RoC with 13.5 as mean ridge density. It was observed that the ridge density of pre-submerged prints was significantly higher than submerged ones. After performing the normality test, it was found that p >0.05, so the non-parametric ‘Friedman test’ was applied to do the statistical analysis.

Table: 5 Descriptive statistics of Pre- Loc, LoC1, LoC2, and LoC3					
	N	Mean	Std. Deviation	Minimum	Maximum
Pre-LoC (Left of centre)	26	14.1154	1.55761	11.00	18.00
LoC1	26	13.4231	1.44701	10.00	17.00
LoC2	26	12.8846	1.27521	10.00	15.00
LoC3	26	12.1923	1.41476	9.00	15.00

Table: 6 Mean ranks of Pre- LoC, LoC1, LoC2, and LoC3	
	Mean Rank
Pre-LoC (left of centre)	3.75
LoC1	2.87
LoC2	2.10
LoC3	1.29

Table:7 Test statistic values	
N	25
Chi-Square	63.651
df	3
Asymp. Sig.	.000

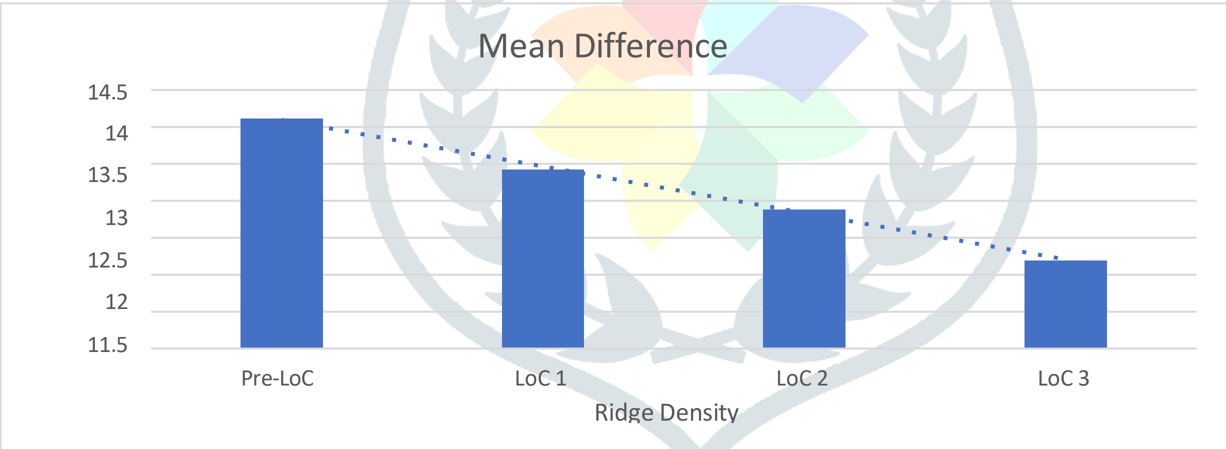
Table: 8 Descriptive statistics of Pre- RoC, RoC1, RoC2, and RoC3.					
	N	Mean	Std. Deviation	Minimum	Maximum
Pre-RoC (Right of centre)	26	16.3462	1.52164	12.00	19.00
Roc1	26	15.6538	1.69570	11.00	19.00
RoC2	26	14.6923	1.46340	11.00	17.00
RoC3	26	14.1538	1.51505	11.00	16.00

Table: 9 Mean ranks of Pre-RoC, Roc1, RoC2, and RoC3	
PreRoC (right of centre)	3.83

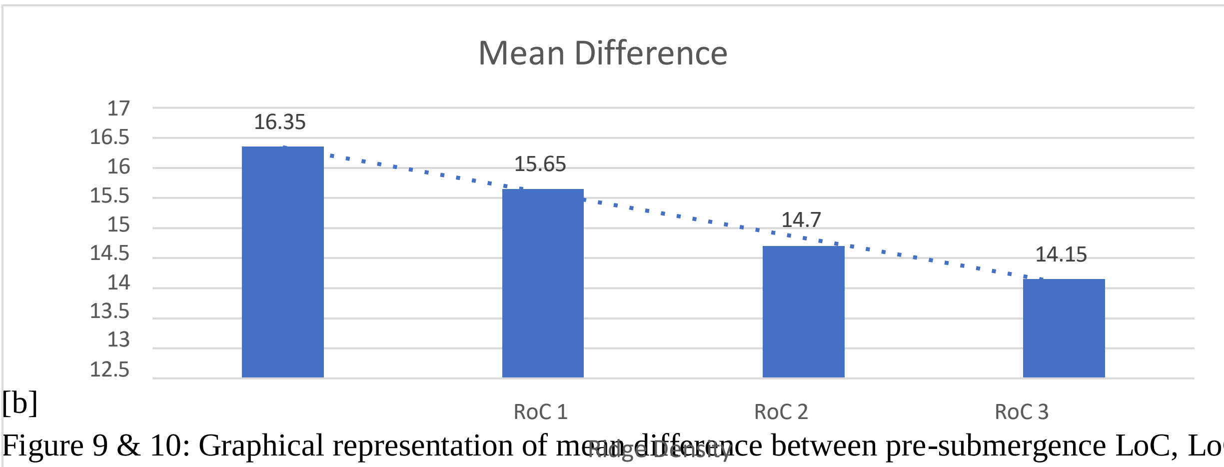
Roc1	2.96
RoC2	1.90
RoC3	1.31

Table:10 Test statistics values	
N	25
Chi-Square	67.915
Df	3
Asymp. Sig.	.000

For non-parametric Friedman test, with N=25, Chi-square=67.915, df=3 and p=0.000 (p value< 0.05) indicate there is mean difference between the Pre-RoC, RoC1, RoC2, and RoC3.
the thumbprint ridge density in LoC and RoC areas of pre-submergence and post- submergence prints analyzed in the study. Pre-submergence prints showed more ridge density than post-submergence prints. Therefore, we can conclude that the ridge density is decreasing in the post-submergence prints taken in 15 minutes,1 hour, and 2 hours' time interval.



[a]



[b]

Figure 9 & 10: Graphical representation of mean difference between pre-submergence LoC, LoC 1, LoC 2 and LoC 3 in [a] and pre-submergence RoC, RoC 1, RoC2 and RoC3 in [b] respectively.

DISCUSSION

Fingerprint plays an important role in forensics because of their uniqueness. Individuals can have the same pattern flow on their fingers, but not the same level 2 and 3 features. These are unique for even two fingers of the same individual. For a positive identification or match of two prints, there should be a minimum of eight minutiae. Pores have been used in forensic applications for a long time because it is more difficult to damage or duplicate than minutiae and also, they are abundant in fingerprints. Pores can be found in even the tiniest fingerprint fragments.

In the present study, the effect of water submergence on fingerprint features is studied. It was found that water-induced wrinkling has no effect on the level 1 feature of the fingerprint as the fingerprint pattern remains the same always. Table 2 shows the number of ridge characteristics or minutiae (level 2 features) identified on the left thumbprint of the subjects in pre-submergence and post-submergence prints. It was found that there was a small decrease in the number of minutiae identified in a few subjects' post-submergence prints. The number of minutiae taken into consideration for positive identification was eight, but in a few subjects, the number identified decreased up to 6 in prints taken after 1 and 2 hours. This is due to the wrinkles formed as a result of water submergence. Because of the presence of wrinkles, the ink was not fully distributed on the finger and it can be prominently observed in the post- submergence prints taken.

Table 3 shows the pore characteristics observed in the prints. In the present study, round - shaped pores were frequently observed. Among the subjects, 48% had a majority of round- shaped pores in the selected 0.5 cm ridge length, and 16% had oval-shaped pores while 48% had a combination of round and oval-shaped pores in the selected area of ridge. The commonly observed pore size was medium. It was observed that 56% had a majority of medium-sized pores in the selected ridge length, 20% had small-sized pores while 24% showed a combination of both medium and small-sized pores. When it comes to the type of pores, this study shows that the majority of the pores observed in the 0.5 cm ridge length were a combination of closed and open pores (68%), followed by open pores (20%), and closed pores (12%). It was found that most of the pores were located in the central portion of the ridge. 64% of pores in the prints were in the central region while 12% were in the peripheral region and 24% were a combination of both. The most commonly seen interspacing between the pores in the prints taken were close and chain-like interspacing (28%), followed by close type (20%), groups with close interspacing and chain-like (20%), groups with close interspacing (20%), and distant spacing (12%).

On the basis of the number of pores present in 0.5 cm ridge length and their configuration, the spacing between pores was estimated and classified into different categories. When there were more than six pores in the selected 0.5 cm ridge length and they lie very close to each other, they are classified as pores with close interspacing. When pores are arranged in clusters of two or more on a 0.5 cm grid, they can be classified as pores in groups with close interspacing. When the number of pores ranges from 4 to 10 (approximately), with a larger gap between them on 0.5 cm ridge length, they are pores with distant interspacing. When the pores create a chain-like appearance, and there is no much space between the two pores, they are classified as pores with chain-like formation.

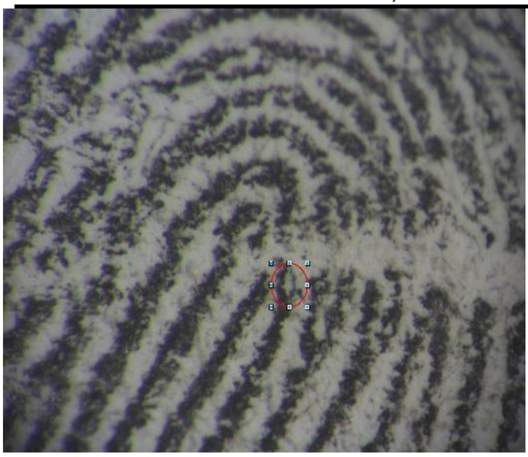


Figure 12: Shows oval-shaped pores on the fingerprints viewed under a stereo microscope at 40x.

Figure 13: Shows round-shaped pores on the fingerprints viewed under a stereo microscope at 40x.

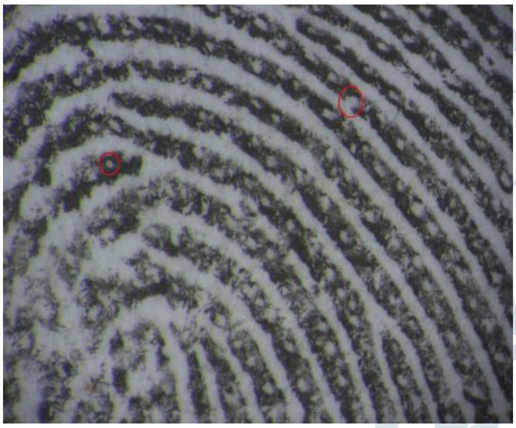


Figure 14: Shows a closed and 1 side open pore viewed under a stereo microscope at 40x

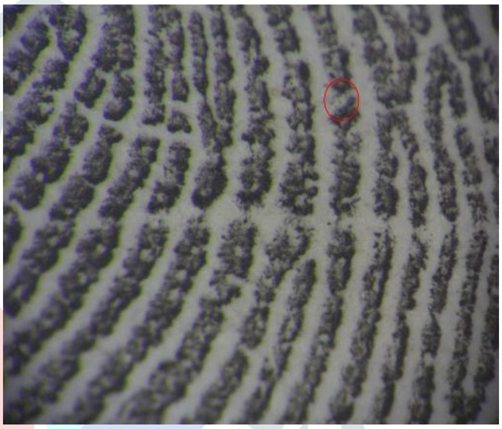


Figure 15: Shows a 2-side open pore viewed under a stereo microscope at 40x

After evaluation of the qualitative results and comparison with the finding of Bindra et.al 2000, and Preethi et.al 2012, it was found that there were some similar findings. In all the studies frequently, observed pores were round in shape, closed, medium-sized, and positioned in the centre of the ridge.

While counting the fingerprint ridge density of pre-submergence and post-submergence prints in the present study, it was noted that the males have fewer FPRD (Fingerprint ridge density) than females, this is because of the higher body proportions and a bigger surface area in males, resulting in the same number of ridges spread across a wider surface. Females have narrow ridge features on their fingers, resulting in more ridge counts in a particular space of a fingerprint area than in males.

CONCLUSION, LIMITATIONS & FUTURE SCOPE OF THE STUDY

This study shows that there is a significant difference in fingerprint ridge density of pre- submergence and post-submergence prints of the same individual taken at different time intervals. This suggests that water-induced wrinkling has an effect on FPRD. It was found that the ridge density is decreasing in post-submergences prints; ridge width is increasing in the selected area on the print. Therefore, we can conclude that as submergence time increases the ridge density decreases. Further research in this area could be useful in fingerprint studies done in drowning cases. From the analysis of pore characteristics, it was found that the majority of individuals possessed round, medium-sized, closed pores situated in the central region of the ridge with close and chain-like interspacing. There was only a slight difference in the number of ridge characteristics identified in the pre-submergence and post-submergence prints. From all the parameters studied in this paper, it can be concluded that there is an effect of water submergence on fingerprint features, especially the fingerprint ridge density. A statistically significant difference was found in the mean differences between ridge density of pre- submergence and post-submergence prints. Further studies can be done on the basis of the findings in this paper, it can be implemented in fingerprint ridge density analysis of deceased in drowning cases. Lake water, River water, sea water and other physical and chemical characteristics of water can be included as different variables to see its varying effects on fingers and consequently on the finger impressions.

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