Family Biometerics: Similar But Different

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***Abstract*— Tongue biometrics has some similarities within families due to genetics, just as fingerprints and toeprints do. Tongue biometrics offers not only a more unique identification tool upon death. The tongue also has the potential to provide secure access. One day, we may see the Transportation Security Authority (TSA) and CLEAR using it to get through airport security lines instead of Real IDs, passports, and retinal scans.**

Keywords— biometrics, family DNA, identification, security)

I. Introduction

In recent years, the criminal justice systems focus has shifted to DNA identification versus biometric identification. Biometrics, such as fingerprints and toeprints, has been shown through research to not only identify individuals, but family traits. As medical technology improves, allowing replacement of thumbs with big toes, it is important to continue research in the biometric area. Tongue print research is limited even though they are just as unique as fingerprints and toeprints.

II. Background

A. Fingerprints

Before Christ (BC's) the Chinese Qin Dynasty recorded details of using handprints as a way to find burglars and Han Dynasty records show clay seals showing fingerprint ridge impressions [23]. Von Minden also indicates evidence of fingerprinting in the 14th century Persian book "Jaamehol-Tawarikh" by Khajeh Rashiduddin Fazlollah Hamadani, there is evidence of Dr. Nehemiah Grew publishing details of friction ridge skin observations in the Royal Society of London paper in 1684, Govard Bidloo writing a book in 1685 about papillary ridges, and Marcello Malpighi at the University of Bologna's work with ridge, spirals, and loops in1686 [23]. French criminologist, Alphonse Bertillon created an eleven point measurement system known as Anthropometrics [7]. The Anthropometry system failed when two people were found to have the same eleven measurements in the Will and William West Leavenworth Prison case [7]. This sparked several scientists to start looking for improved ways to identify people by their fingerprints. The judicial failure of anthropometrics to modern fingerprinting can be see the following list [7]; [23]; [21]; [6]; [8]; [22]:

- 1893 – The London Metropolitan Police known as Scotland Yard, includes fingerprints to the Bertillon cards for criminal identification
- 1902 – The New York Civil Service Commission uses fingerprinting to determine if test takers and workers were the same people
- 1903 – Inmates in the New York prison and Leavenworth Prison along with St. Louis PD starting to fingerprint criminals
- 1905- U.S. military starts fingerprinting soldiers
- 1915 – The International Association for Criminal Identification/International Association for Identification (IAI).
- 1918 – Twelcve point differences identified to provide positive identification.
- 1924 – The Federal Bureau of Investigations (FBI) created the Identification Division
- 1977 – New Orleans, Louisiana created Certified Latent Print Examiners (CLPEs) test.
- 2014 – U.S. Automatic Fingerprint Identification System (AFIS) became the largest database in America with most being two fingerprint records instead of the traditional ten fingerprint records
- 2014 – World's largest fingerprint database is the Unique Identification Authority of India (UIAI) with over 560 million fingerprint, face and biometric records.

The classification system that is used today evolved from a method developed by Sir Edward Henry who was in collaboration with Sir Francis Galton, Sir William Hershel, and Dr. Henry Faulds [7].

B. Toeprints

Trying to classify toeprints and footprints to identify crime victims and to help catch criminals is not new. In 1927, Robert Montgomery published an article in the Journal of Criminal Law and Criminology on how to classify them. This publication focused on the early start of hospitals taking newborn footprints as a way to identify the newborn [12]. The hospitals take the thumb print of the mother and the toeprints of the newborn. The belief was that they would be similar enough to each other the two could be easily paired up. The tradition of hospitals doing footprints of newborns is still done in most hospitals, but more for a keepsake of the birth. To date there is no mandatory law or database that the hospitals are required to put newborn footprints in. Montgomery explains how a toeprint classification system designed by H.H. Wilder in 1918 "has only 17,600,000 theoretical possibilities" and would be very useful with as little as a couple hundred of prints [12]. Moorthy and Sulaiman attempted to help solve crimes in Malaysia by collecting

footprints of over 400 adults consisting of 200 males and 200 females using a traditional ink pad fingerprint approach [13]. They recorded "various features of the toes, humps in the toe line, phalange marks, flatfoot condition, pits, cracks, corns" and other characteristics items [13]. Moorthy and Sulaiman also compared their findings to those done previously with Indian's and found that the morphological length of toes was different and that toeprints were affected by nationality and genetic makeup [13].

According to Burrow, one disadvantage of using toeprints instead of fingerprints is the Reels phenomenon which is a ghost image or shadow that appears two-dimensional within latent prints [4]. "This phenomenon has implications for the collection and interpretation and thus the comparison made between unknown and known footprints in the criminal justice system" [4]. This is one recent look at toeprints and the impact on the criminal justice system, but it is not the first. There was an article in Fingerprint and Identification Magazine from March 1953 titled "The Case of the Great Toe Print". The police found a toeprint on a safe that was stolen during a robbery on June 29, 1952 and the lawyer Lord Binarm asked for a guilty verdict based on the toeprint alone [17]. After a divesting earthquake in Japan in March 2011, coroners decided to use footprints to identify 75 unidentified bodies based on their toe ridges [2]. Beall also reported that this method could be used to identify dementia patients and there was a possibility of a ride pattern right under the toe area that could also be used. However, the ridge pattern below the toe area needed to have a new classification system developed as it did not follow the same ridges as the fingerprints [2]. In 2010, police identified 19-year old Colton Harris-Moore, aka: the barefoot bandit, through his toe prints [16]. The same friction ridge classifications used for fingerprints; can be used for toes, lips, elbows and ears [16].

C. *Tongueprints*

Tongue prints are different because of the tongue is different from the fingers and toes as it is an internal organ that is covered in a mucous coating [19]. The part that makes tongue prints hard to collect is the mucous coating on the surface. The other thing that makes the tongue itself unique it that it is the only internal organ that can be stuck out of the body and into another environment [19]. The shape of the tongue can be determined by either physical observation or several math calculations. Bob Zhang and Han Zhang were able to create a set of thirteen calculations that could determine five different tongue shapes [24]. The five shapes their calculations could identify are rectangle, acute triangle, obtuse triangle, square and circle [24]. Bob Zhang and Han Zhang's set of calculations included width, length, length-width ratio, smaller half distance, center distance, center distance ratio, area, circle area, circle area ratio, square area, square area ratio, triangle area, and triangle area ratio [24]. Suryadevara, Naaz, Shweta, Kapoor, and Sharma [20] showed how tongues have a unique shape and texture that could be used in banking applications. Due to the uniqueness of the tongue they proposed the use of a 3D model to acquire accurate shape and texture information of tongue, just as this research study did. "The human tongue promises to deliver a level of uniqueness to identification applications that other biometrics cannot match in context of that it is well protected in mouth and is difficult to forge.

The tongue also presents both geometric shape information and physiological texture information which are potentially useful in identity verification applications" [20] as seen in Fig. 1 and Fig. 2.

Fig. 1, Examples of different shape from frontal view [11,14].

Fig. 2, Examples of different textures on the tongue [11,14].

As Suryadeva et. al. points out the tongue is the only internal organ that someone can easily expose for inspection and validation [20]. The tongue also provides a stability over time that other biometrics do not. "The physiological and behavioral characteristics that have so far been developed and implemented are long and include the face, iris, fingerprint, palm print, hand shape, voice, signature and gait. However, the traditional biometrics has an inherent limitation in that they are easily forged" [14]. This research not only looked at the tongue itself, it also look at the shape of the persons face as a possible method to increase reliability of current facial recognition systems. Zhi Liu, Jing-Qi Yan, David Zhang, and Qun-Lin Tang in their research attempted to create a tongue repository by evaluating 134 participants' tongues, no such universal database has been accepted [11]. While this research did not focus on creating a databases system, it is something that needs to be developed further as interest in tongue biometrics grows and before it could be used by the criminal justice system.

III. Preliminary Finger and Toeprint Research

The fingerprint research study completed by the author on full-blooded siblings which included three major classes and the five minor classes with a four fingers test, only one sibling set had less than 40% similarity. The findings also indicated that the right index finger of all sets had a median of 40%, even within Set 8 that had only a 20% match on the right thumb. The left thumb for Set 8 showed a mode of 40%. The next highest percent of similarity was at 20%, yet the sibling set that had the lowest right thumb similarity had the highest right thumb similarity at 60%. The mode for the left index fingers was 40% with 12 of the 15 sibling sets being at that level. The final fingerprint study conclusion was that similarity overall, even though they may have slight differences within some classifications with all sibling sets having at least an 80% match. These findings supported the prior research findings from [25] that states while everyone has a unique fingerprint, siblings do have similarities based on generics during fetus development. One set of siblings had a participant who was created with vitro fertilization and one who was not.

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The toeprint research study completed by the author analyzed for the major classifications and five specific ridge classifications of fully related siblings. The major classifications that were looked for in the toeprints are whorls, arches, and loops. The five specific ridge classifications that were looked for in the toeprints are fork, double fork, triple fork, short ridge, and ending ridge. The study found that the average ridge classifications similarity was 83%. The average right big toe similarity was 88% and the left big toe similarity was 78%. The average major classification was 55%. Overall the study found that fully related siblings have similarities with most of the sibling sets ridge classifications being 80% similar and three of them 90% similar. While the similarity of the ridge classifications didn't vary much the similarity of the major classifications varied.

IV. Pilot Tongue Study Summary

A. Procedures

Following human research safety precautions and ensuring participant identification was protected as small tongue print collection was done. The collection on the tongue print was done in two steps. The first step was taking a picture of the tongue with the Apple iPad Air camera. The second step was taking a 3D scan of tongue with the 3D iSense scanner. After the tongue print was collected, the researcher saved the two files with the participant's alphanumeric identifier. After tongue prints were collected, the researcher analyzed each of the prints individually before comparing them to family members. The picture of the tongue collected with the Apple iPad Air camera was analyzed first. They were analyzed first since only the shape was being looked at. Next, the 3D scan of the tongue was analyzed for characteristics on the tongue. The small pilot study included two families and one control, nine participants in total, who were tongue printed. The tongue prints were analyzed for tongue shape, vertical fissures, and horizontal fissures. The tongue shapes that were looked for are U-shape and V-shape. The vertical and horizontal fissures that were looked for are singular, multiple, straight, wavy, shallow, and deep.

The width (w) of the tongue was measured by horizontal distance along the x-axis from a tongue's most right edge point ($x$max) to its furthest left edge point using the equation: (x_{min}): $w = x_{max} - x_{min}$ [24]. The length (l) of the tongue was measured as the vertical distance along the y-axis from a tongue's furthest bottom edge ($y$max) point to its furthest top edge point ($y$min), with the equation: $l = y_{max} - y_{min}$ [24]. The length-width ratio (lw) was calculated using the equation: $lw = l/w$ [24] the center distance (cd) is the distance from the width's y-axis center point to the length center point l(ycp) [24] to create the below equation.

$$cd=((\max(y_{xmax})+\max(y_{xmin}))/2)-y_{cp}$$

$$\text{where } y_{cp} = (y_{max} + y_{min})/2 \text{ [24]}$$

B. Findings

The two tongue shapes found within the pilot study was U and V shaped as seen in Fig. 3.

Fig.3, U-Shaped (R) and V-Shaped (L)

The data showed that U-shaped tongues are more common than V-shaped tongues as seen in Table 1. This is shown as 66% of the participants had U-shaped tongues. The data also showed that vertical fissures were more common than horizontal fissures as seen in Table 2 and Table 3. This is shown as only two participants had horizontal fissures and all other participants had vertical fissures. Both of the participants' horizontal fissures were shallow and located in the same general area. The majority of the vertical fissures were straight, but most of them came from participant's having multiple vertical fissures on the tongue. Only two participants had wavy fissures and those fissures were vertical. All of the vertical fissures were located in three general areas.

TABLE 1. TONGUE SHAPE RAW DATA TABLE

	Tongue Shape	
Participant:	**U-Shape**	**V-Shape**
F-A1	X	
F-A2	X	
F-A3	X	
F-A4	X	
F-A5	X	
F-B1		X
F-B2		X
F-B3		X
C1	X	

Family A is a 100% similar in tongue shape as those in the family all have U-shaped tongues. Family B is also 100% similar in tongue shape as those in the family all have V-shaped tongues. The Control followed the U-Shape of Family A.

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TABLE 2. VERTICAL FISSURE RAW DATA TABLE

	Vertical							
	Singular				Multiple			
	Straight		Wavy		Straight		Wavy	
Participant:	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
F-A1	X							
F-A2		X						
F-A3	X							
F-A4					X	X		
F-A5							X	X
F-B1				X				
F-B2					X	X		
F-B3	X							
C1					X	X		

Four members of Family A have straight vertical fissures and the fifth has wavy vertical fissures as recorded in Table 2. Three of the four that have straight vertical fissures only have a fissure present on the tongue. Two of the fissures are shallow and one of the fissures is deep. The fourth has three straight vertical fissures present on their tongue that are both shallow and deep. The two fissures on the edges of the tongue are deep and the last fissure is shallow and in the center of the tongue. The fifth member of the family has three wavy vertical fissures that are both shallow and deep on the tongue. The two fissures on the edges of the tongue are shallow and the last fissure is deep and in the center of the tongue.

Two members of Family B have straight vertical fissures and the third member has a wavy vertical fissures as recorded in Table 2. One of the two that have straight vertical fissures has only one fissure present on their tongue and it is shallow. The second member has three straight vertical fissures that are both shallow and deep present on their tongue. The two fissures on the edges of the tongue are shallow and the last fissure is deep and in the center of the tongue. The third member of the family has a fissure present on their tongue that is deep and wavy.

TABLE 3. HORIZONTAL FISSURE RAW DATA TABLE

	Horizontal							
	Singular				Multiple			
	Straight		Wavy		Straight		Wavy	
Participant:	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
F-A1								
F-A2								
F-A3	X							
F-A4	X							
F-A5								
F-B1								
F-B2								
F-B3								
C1								

The two members of the Family A that have straight shallow horizontal fissures have them in the center and on the lower half of the tongue. None of the members of Family B or the Control had horizontal fissures on the tongue as recorded in Table 3.

V. Conclusion & Future Research

The results of this pilot study provide additional support of a study done in 2015 on the main geometric shape of the tongue for people with specific diseases [24] Although some tongue biometric research has been done in countries such as China, India, and Romania; there is limited such research being completed within the United States. While tongues open up a new biometric pathway to combat identity theft and other shortcomings of currently used biometric systems, it will take more studies and expansion for this research before tongue biometrics become mainstream. One of the biggest hurdles is the initial reaction of the public in sticking out their tongue in public at an ATM or at the office to enter into a room.

Future research includes looking at more characteristics and shapes of the tongue. More research on the shape of the tongue can be to see if it could provide information to health care providers about possible diseases one may have like diabetes, epilepsy, and dementia. The color of the tongue can also be examined to see if it has any relationship among family members and medical issues. Since the tongue is unique, there is many ways to collect tongue prints which leads to many more research opportunities, but the first big hurdle is the creation of a globe tongue database. The second hurdle is to discover a standard way to collect tongue prints, as currently researchers are using a variety of methods.

Acknowledgments

This author would like to thank Lord Fairfax Community College Professors Robert Gehringer and Dr. Melissa Stange for their technical and research guidance. I would also like to thank Science teachers Mrs. Barbara Agregaard and Mr. Lance Moss who encouraged me to pursue my science and biometric interest. Also, to Dr. Paul Lyons for spending time discussing my tongue research and the possibility of furthering my study for more automation and use in the medical profession for possible determination of epilepsy. Additional thanks to all of the research participants.

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