- Uniqueness of Tongue Characteristics
- Tongue Surface Analysis for Human Identification
- Ethical Concerns in tongue analysis.

The Uniqueness of Tongue Characteristics

The tongue has very unique characteristics, especially its dorsal surface. Which proves to be a very important key when we consider tongue to be a potential tool in human identification or as a biometric identifier for human forensic identification. Here we will review the literature to understand the evidence or proof to support the uniqueness of the tongue, its morphology and its surface details.

Multiple studies have been done to investigate the unique nature of the tongue in comparison to other biometric identifiers. Fingerprints and iris which are other biometric tools can undergo minor changes over time due to multiple external factors but tongue morphology is considered to be more consistent and stable relatively.

Gaganpreet K and Dheerendra S. 2015 have stated that Tongue print is a unique biometric tool that cannot be forged easily. Advantages of tongue prints over other biometric systems are genetic independence as no two tongues are similar, physical protection as it is encased inside the mouth and its stability over time.[15]

A study by Diwakar and Maharshi, 2013 reported the tongue as a reliable member of the biometrics family.[16] Application of the tongue biometrics system in a public use system such as the banking system has been proved by Naaz et al. in 2011.[17] There has been significant research in biometrics over the last two decades. No biometric has yet been developed that is perfectly reliable or secure. For example, fingerprints and palm prints are usually frayed. Signatures, Voice, hand shapes, and iris images are easily forged. Face recognition can be made difficult by occlusions or face lifts, and biometrics such as fingerprints, iris, and face recognition are susceptible to spoofing attacks.[18]

Traditional biometrics like face, iris, fingerprint, palm print, and voice have been used in biometric authentication but has an inherent limitation in that they are easily forged. Research on the tongue print recognition system was first proposed by Liu et al. in 2007.[19]

Numerous advantages exist in using tongue print because lingual morphological aspects are difficult to forge and display stability over time. The use of photographs as

forensic identification remains unexplored in the field of dentistry. The geometric shape of the tongue is usually constant, and surface texture varies due to pathological changes of the body. [20, 21]

Studies on tongue surface features and their uniqueness for human identification have been conducted and the researchers the results demonstrated that tongue features showed a remarkable level of individual distinctiveness, even among identical twins.

Other studies have explored the potential of combining tongue analysis with other biometric modalities for multimodal biometrics. For instance, Zhang et al. (2018) investigated the fusion of tongue and facial recognition for enhanced human identification. Their research found that the fusion of tongue and facial biometrics resulted in improved accuracy and reduced false acceptance rates compared to using either modality alone. [18]

While the existing literature shows promising evidence of the uniqueness and stability of tongue characteristics, it is essential to acknowledge potential limitations. The sample sizes in some studies may be relatively small, and further research with larger and more diverse populations would strengthen the findings. Additionally, the accuracy of tongue-based identification may be affected by certain factors, such as tongue positioning during imaging or variations in imaging devices.

In conclusion, the reviewed literature provides enough evidence suggesting the uniqueness of tongue characteristics for human identification. The dorsal surface of the tongue exhibits distinct features that are consistent among individuals and remain stable over time. With further research and advancements in imaging technologies, the tongue holds great potential as a reliable and robust biometric identifier, contributing to the field of forensic science and beyond.

Tongue Surface Analysis for Human Identification

Tongue surface analysis for human identification is an emerging field that holds promising potential as a reliable biometric identifier. This section will review relevant literature to explore the use of tongue surface features for individual identification and its applications in forensic science and security.

The uniqueness of the tongue print is that no two tongues are the same, and studies have found that the tongue of identical twins also does not resemble each other.[22]

Database creation is mandatory to explore the use of tongue prints in forensic dentistry. Dentists can play an important role by collecting images of the tongue and prepare a cast routinely for the patients along with their other dental records. This would serve as a database and a guide for identification purposes. To conclude, tongue print being a unique record and one that cannot be forged is a better biometric authentication tool than others, and since it is personalized and constant, it can be used for forensic identification purposes too.[20]

Sivakumar et al in 2018 stated that the tongue can be considered a good biometric system since it fulfils all the parameters, particularly the one regarding circumvention which is a problem with existing biometrics such as fingerprints. The tongue is less susceptible to forgery due to its well protected nature and consent is needed for its inspection, which might not be the case for other biometrics such as fingerprints. One of the main questions regarding this novel mode of identification is how to analyze it for such purposes. A group of researchers has reported a 97.05% accuracy rate in identifying people via their tongue by acquiring images of the patterns on the tongue and comparing pixel intensities of those images [23]

The reviewed literature provides valuable insights into the use of tongue surface analysis for human identification. Studies have demonstrated the uniqueness and stability of tongue surface features, supporting its potential as a reliable biometric identifier. The development of tongue-based identification systems and the exploration of multimodal approaches show promise in enhancing identification accuracy and security. As research in this area continues to expand, tongue surface analysis may contribute significantly to the field of forensic science and other security applications.

Ahmed Shallal Obaid et al. 2023 discussed about the uniqueness of the tongue and mentioned that it is well protected hence difficult to forge. They pointed out various aspects in their paper like how traditional biometrics cause obstacles and challenges in investigations and can be easily forged and are very expensive. New more secure less expensive and reliable systems should be used in today's modern world, ditching the traditional methods. This will increase security measures. [24]

Poojya R. 2023 in a paper discussed Tongue print or lingual impression is a new biometric authentication method used in forensics. That recent advances have been made using uniqueness of the tongue as a valid fact. She documented that algorithms

for tongue image analysis have been prepared. lingual moulded impressions, Digital photographs, rugoscopy, cheiloscopy, ultrasound, histological analysis are some ways of tongue print collection. She stated that there is an urgent need for more secure authenticated forensic tools like the tongue prints. This should be considered and used.[25]

Bansal et al. 2021 stated that tongue prints can be used as an adjunct to other biometric systems. Hence creation of a good database is very important. He also state the advantages of tongue prints. [26]

Latif H. 2020 stated that the term biometrics is taken from two ancient Greek words 'bios' and 'metron,' which mean 'life' and 'measure' respectively. It involves the identification of humans based on intrinsic physical or behavioural traits that are unique to individuals. [27]

Physical characteristics most used as modes of identification include fingerprints, dental records, the iris, and facial recognition amongst others whereas behavioural characteristics used for identification purposes include voice recognition, handwriting, keystroke patterns. Although identification by biometrics is never 100%.

Pradkhshana et al . 2019 formulated a Working classification system of tongue pattern after conducting a study on 30 individuals (15 male and 15 females) where they used digital images to record information.[28]

Working classification formulated by Pradkhshana et al. 2019 [28]

1	Size of tongue	Small and	Large				
2	Shape of tongue	Long and Broad	long and narrow	short and broad	short and narrow		
3	Colour of tongue	Pale	Pink	Reddish	Whitis h	Brown	Pigmen ted
4	Texture of tongue	Smooth	Rough	Ulcerate d	Hairy,	Edemat ous	Nodula r
5	Pattern on tongue surface	1. Fissured: V shaped, Coated	2.Branched: -Horizontal -Vertical	Pattern less	Cleft	Geograp hic pattern	Hairy tongue

		tongue					
6	Margins of tongue:	Smooth	Scalloped	Ulcerated	Nodular		
7	Tip of tongue:	Pointed (V shaped)	Blunt (U shaped)				

Sivakumar et al. 2018 discussed the modes of identification and analysis mentioning how a group of researchers reported 97.05% accuracy rate in human identification by their tongue. This was done by taking images of the tongue patterns and comparing pixel intensities of those pictures. They further converted these images into 3 D plots of pixels of the image giving the researchers unique plots for each image. [23] They also documented about the researchers suggesting that the tongue exhibits sexual dimorphism which again can aid in human identification. Our study also has significant data proving sexual dimorphism. These researchers used alginate impressions to match the tongue getting 90% matching rate.

Abraham Johnson et al. 2018 conducted a study on 225 people (male and female) of age group 20 to 50 and concluded that [8]

GEOGRAPHIC TONGUE	FEMALE MORE THAN MALE Also corelated with Stefansu et al
PLAQUED TONGUE	MORE IN ELDERLY MALES
GEOGRAPHIC TONGUE > SCROTAL TONGUE	Abraham Johnson et al
SCROTAL TONGUE > GEOGRAPHIC TONGUE	Stefansu et al

Reddy MV et al. 2017, Suggested that the unique characteristics of the tongue are impossible to be reverse engineered. Tongue prints have way superior quality than other biometric systems used traditionally. He stated the use of lingual templates or tongue templates with two lateral views (left and right) and one profile views.[29]

Reddy MV et al also discussed that when comparing tongue scanning to other biometric techniques Tongue due to its uniqueness and anatomy has many advantages[29] like

Characteristic features	Unique shape and texture in each individual
Projected when required	It's an internal organ but can be struck out for inspection
Unaffected by environment	As it is protected and encased in the oral cavity it is not affected by the external environment
Inspected with Permission of the individual	only with the consent of the individual can the tongue be examined hence chances of forgery are less

Zang B and Zang H ,2015 Suggested that a cast can be used to transfer the unique features of the tongue and later used for studies. Digital software for colour and hue corrections of the tongue are used to match with the digital databases. The mentioned that algorithms are being used for image analysis of the tongue.[30]

Many authors on the basis of features observed on the dorsal surface of the tongue made classifications for the ease of other researchers. Like Stefanescu CL et al. 2014.[31]

CLASSIFICATION OF FEATURES ON THE DORSAL SURFACE OF THE TONGUE		
TEXTURAL VARIATIONS IN TONGUE	SHAPES OF TONGUE	TONGUE GEOMETRY FEATURES
TONGUE FISSURES OF TONGUE CRACKS	ELLIPTICAL	LENGTH
SMOOTH TONGUE	HAMMER	WIDTH
	RECTANGULAR	THICKNESS
	ACUTE TRIANGULAR	
	OBTUSE TRIANGULAR	
	SQUARE	
	ROUND	

CLASSIFICATION OF TONGUE FEATURES by Stefanescu CL et al.			
TONGUE TEXTURE	SHAPES OF TONGUE	LONGITUDINAL GROOVES	LINGUAL APEX
PHYSIOLOGICAL	OVOID	PERCEPTIBLE/ IMPERCEPTIBLE	SHARP
SCROTAL	ELLIPSOID	RECTILINEAR/TWISTY	SEPTATE
GEOGRAPHICAL	RECTANGULAR	SUPERFICIAL /DEEP	
	PENTAGONAL		
	TRAPEZOIDAL TO ASYMETRICAL		

Menard L et al. 2012 developed an ultrasound technique using an ultrasound transducer. The process involved placing it in the sublingual area to analyse the tongue function. [32]

Bhattacharyya D et al. 2009 stated that tongue is a very good biometric tool as the other tools like finger prints, voice, skin colour, retinal scans all prove to have some shortcomings affecting their reliability and stability.[33] He also documented the disadvantages of various biometric systems:

Disadvantages of various biometric systems: Bhattacharyya D et al. 2009	
FINGER PRINTS	CHANGED BECAUSE OF WORK, ERODED, ALTERED DUE TO SURGERY, CHANGE CAUSED BY BURNS, INJURIES HENCE NOT STABLE
VOICE	ALTERED BY SICKNESS, COLD AND COUGH, EMOTIONAL PROBLEMS
SKIN COLOUR	CHANGES DUE TO AGE, DISEASES BURNS, ADVERSE EFFECTS OF TOPICAL CREAMS OR MEDICATIONS.
RETINAL SCAN	DISEASES LIKE ASTIGMATISM, CATARACT OR BRIGHT LIGHT.

Yan Z et al. 2009 discussed that as tongue is a non-rigid organ images can be extracted in study by the help of capturing a video. He mentioned another method which is sublingual vein analysis method used for diagnosis of tongue.[34]

Multiple techniques have been employed to evaluate tongue prints and one such mention was made by **Liu Z et al**, that a polytechnic university in Hong Kong developed a tongue image database which captured both surface textures and geometric shape of the tongue (3-dimensional analysis of the tongue) This could prove as a very important base for information in assessments, comparisons and evaluations of tongue patterns.

Liu et al. 2007 stated that the tongue is an internal organ which is well encased and protected in the oral cavity, which makes it less prone to being reverse engineered. The pattern of the ridges on the tongue along with the shape of the tongue and its texture are quite unique to every individual. Most importantly these tongue characteristics are thought to remain unchanging over time. All these features of the tongue make it a fine biometric tool. [35]

Jain et al. 2005 mentioned different parameters that need to be fulfilled for a trait to be considered a biometric tool

A	UNIVERSALITY	EVERY PERSON SHOULD POSSESS THE TRAIT.
B	DISTINCTIVENESS	EACH PERSON SHOULD BE UNIQUE FOR THE TRAIT.
C	PERMANENCE	THE TRAIT SHOULD REMAIN RELATIVELY STABLE OVER TIME
D	COLLECTABILITY	THE TRAIT SHOULD BE EASILY MEASURABLE.
E	CIRCUMVENTION	THE TRAIT SHOULD NOT BE DISPOSED TO EASY IMITATION, REVERSE ENGINEERING OR FORGERY.

The tongue proves to be a good model as a biometric since it fulfils all these constraints, especially the one regarding circumvention which is a problem with existing biometrics such as fingerprints. Also, the tongue is less prone to forgery due to its well protected nature also consent is needed for its inspection, which might not be the case for other biometrics such as fingerprints. [36]

(OECDiLibrary 2004) This article discussed that biometric based systems operate in similar manner which involves Biometric Sample captured, digitalizing it, perform

feature extraction or data set creation then tune the sample ultimately match the input sample with known samples in database.[37]

Ethical Concerns in tongue analysis.

Any form of data required for forensic or biometric identification has many ethical and legal concerns which need to be dealt with and handled with a lot of sensitivity. The data we are handling during the study of tongue analysis or other forensic investigations involves a lot of data which is private and sensitive. Hence documented below are some points to be kept in mind:

1. Consent to be always informed. Any form of study using data from individuals requires a prior informed consent. It is of paramount importance to protect the privacy of the subject. Every individual should be completely be aware about the reason, risks and benefits of the examination or data collection for the study. We should make sure that the rights of every individual should be protected.
2. Protection of data: Biometric data or data collected for the study of tongue needs to be stored very carefully so that there is no access without permission. Data protection regulations should be followed religiously.