

Tongue Morphometry: an Ancillary for Sex Determination and Personal Identification

Francis Kofi Sarkodie

sarkodiefrancis1985@yahoo.com

Kwame Nkrumah University of Science and Technology

Chrissie Stansie Abaidoo Abaidoo

Kwame Nkrumah University of Science and Technology

Joshua Tetteh

Kwame Nkrumah University of Science and Technology

Raymond Saaru-Eru Maalman

Department of Basic Medical Sciences, School of Medicine, University of Health and Allied Sciences, Ho, Volta Region, Ghana.

Emmanuel Ansah Owusu

Komfo Anokye Teaching Hospital, Kumasi, Ghana

Ronald Awoonor-Williams

Kwame Nkrumah University of Science and Technology

Thomas Koukou Diby

Kwame Nkrumah University of Science and Technology

Samuel Bimpong

Kwame Nkrumah University of Science and Technology

Atta Kusi Appiah

Kwame Nkrumah University of Science and Technology

Nancy Darkoa Darko

Kwame Nkrumah University of Science and Technology

James Nketsiah

Kwame Nkrumah University of Science and Technology

Collins Adjei-Antwi

Kwame Nkrumah University of Science and Technology

Clement Nsobire Atobiga

Kwame Nkrumah University of Science and Technology

Juliet Robertson

Kwame Nkrumah University of Science and Technology

Samuel Kwadwo Peprah Bempah

Kwame Nkrumah University of Science and Technology

Daniel Kobina Okwan

Kwame Nkrumah University of Science and Technology

Ethel Akua Achiaa Domfeh

Kwame Nkrumah University of Science and Technology

Priscilla Obeng

Kwame Nkrumah University of Science and Technology

Sarah Owusu Afriyie

Kwame Nkrumah University of Science and Technology

Research Article

Keywords: Biometric system, Binary Logistic regression, Forensic Odontology, Image J software, Tongue print

Posted Date: May 8th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9377416/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations:

No competing interests reported.

Tables 1 to 6 are available in the Supplementary Files section.

TONGUE MORPHOMETRY: AN ANCILLARY FOR SEX DETERMINATION AND PERSONAL IDENTIFICATION

ABSTRACT

Background: Tongue prints have emerged as a novel biometric identification system in the field of forensic odontology due to their individuality and minimal susceptibility to manipulation. However, data on their use in predicting the sex of individuals is scanty, especially in developing countries like Ghana. This study aimed at evaluating the morphological and morphometric features of tongue prints and assessed their potential for sex prediction in a Ghanaian population. A convenience sampling technique was employed to sample a total of 350 participants (140 males, 210 females) aged 18-42 years. Digital images of the tongues of participants were taken using a Canon EOS 1200D digital camera. Morphological features (shape, colour, apex, margin, surface pattern, and fissures) of the tongue were assessed visually, while tongue dimensions were measured using ImageJ software. Associations between tongue characteristics and sex were analysed using Pearson's Chi-square test. Binary logistic regression was performed to evaluate the predictive value of tongue dimensions for sex determination. **Results:** Pale pink tongue, U-shaped, smooth margin, physiologic surface, absence of fissure, and blunt apex of tongue were the most predominant morphological features. None of the morphometric variables showed a statistically significant association with sex ($p < 0.05$). Logistic regression analysis demonstrated sexual bias and limited predictive performance, correctly classifying 63.7% of cases overall (22.9 % males; 91.0 % females). Tongue length and width were sexually non-dimorphic. The Receiver Operating Characteristic curve was used to determine how well the tongue dimensions could distinguish between both sexes. **Conclusion:** The overall predictive accuracy is low, limiting its reliability as

a solitary forensic tool. Tongue morphometry may be better suited as a complementary means together with established identification methods.

KEY WORDS: Biometric system, Binary Logistic regression, Forensic Odontology, Image J software, Tongue print

1.0 INTRODUCTION

The tongue is a distinctive organ that differs between individuals, making tongue impressions a promising biometric tool. It is difficult to fake the tongue print of a person. In biometric authentication, the identity of a person is determined by comparing the input sample to a sample template. Many biometric techniques, including fingerprint, palm print, iris scan, and signature scan, among others, are currently used (Venkatesh *et al.*, 2019). Each system has flaws that render it vulnerable to security breaches. The most used biometric authentication method is fingerprint. However, they can change after surgery, be degraded by injury, and burns. A retinal scan is very sensitive and may be impacted by conditions like astigmatism and cataracts. The difficulty with using skin colour for biometrics is that there are noticeable variations with age, burns, illnesses, and the use of skin treatments (Venkatesh *et al.*, 2019). The most recent advancement in forensic odontology is the use of tongue prints. The use of tongue prints as a forensic technique is justified because, despite being well protected from environmental influences, the characteristic features of the tongue differ noticeably between individuals, even identical twins. Males have a longer and wider tongue than females. According to a previous study by Sreepradha *et al.* (2019), U-shaped tongues were more common than bifid and V-shaped. Also, males exhibited the U-shape more frequently than females. Females were more likely than males to have V-shaped tongues (Avhad, 2021). Jayan *et al.* (2019), reported that V-shaped tongue was more common in females than in

46 males whereas a U-shaped tongue was more common in both males and females. Avhad (2021)
47 attributed the V-shaped tongue to the decreased mandible size in females compared to males. In a
48 similar study by Panchami and Parida (2021) in Sawangi-Meghe, Wardha, India, more females
49 were found to have the U-shape and bifid tongues, whereas none of the sexes exhibited the V-
50 shape. Males are more likely to have geographic tongue than females (Rezaei *et al.*, 2015; Vijay
51 *et al.*, 2019). Rezaei *et al.* (2015) reported that geographic tongues are plicated (fissured).
52 Geographic and scrotal tongues were common characteristics of females(Johnson, 2018;
53 Stefanescu *et al.*, 2014), whereas scalloped borders of the tongue were predominant and were
54 observed more in males than in females (Chaulagain *et al.*, 2022). In a similar study, Sreepradha
55 *et al.* (2019) reported that smooth tongue was the most predominant. In their study, females
56 recorded scalloped tongue borders more than males. The scalloped tongue border is formed by
57 tooth indentations around the edges of the tongue. It is created by the negative pressure in the oral
58 cavity caused by parafunctional habits (such as cheek sucking, bruxism, tongue thrusting, and
59 sleep disorders). On the contrary, Avhad (2021) found that, scalloped borders were more common
60 in males than in females, whereas smooth borders were mostly found in females than in males.
61 Multiple fissures were the most common fissure type observed in Bangalore, India in a study
62 conducted by Sreepradha *et al.* (2019). It was also reported that, females exhibited absence of
63 fissure more frequently than males whereas Multiple fissures were more predominant in males
64 than females. Females were observed to have single fissures more frequently than males. The
65 relationship between fissures and sex were found to be statistically significant ($p < 0.05$)
66 (Sreepradha *et al.*, 2019). In a related study in Satara district, Maharashtra, in India, Avhad (2021)
67 recorded more Multiple fissures in females compared to males, whereas single fissures were
68 predominant in males. Data gathered from tongue parameters, most notably cheiloscopy,

rugoscopy, and more recently tongue prints, are also capable of contributing significantly to criminal investigations where they act as an adjuvant in sex determination, population subtyping, and individual identification. There is a dearth of data on sex determination using tongue print. Therefore, this study sought to determine the sex of an individual using tongue dimensions.

2.0 MATERIALS AND METHODS

2.1 Study Design and Area

The study employed a cross-sectional mixed methods design, incorporating both quantitative and qualitative approaches. The present study was conducted from June 2023 to April 2025. A convenience sampling technique was employed to sample a total of 350 participants, 140 males and 210 females aged 18-42 years. The study adhered to the Helsinki Declaration, and ethical approval was obtained from the Committee on Human Research, Publications and Ethics, Kwame Nkrumah University of Science and Technology (KNUST), with reference number CHRPE/AP/1153/25. Informed participant's consent was obtained from the students of KNUST, School of Medical Sciences from each participant.

2.2 Sample size

A calculated sample size of 350 was used. The sample size was calculated via Yamane's formula (1967).

95% confidence level, n = Sample size,

N = Student population of KNUST (In the year 2023) = 8,5000

N = 85,000 e = Level of precision or sampling error

$$n = \frac{N}{1+N(e)^2}$$

91
$$n = \frac{85000}{1+85000(0.05)^2}$$

92
$$n = 399$$

93 Missing data/Attrition rate: 10% of 399 =39.9

94
$$n = 350$$
 (Adam, 2020)

95

96

97 **2.3 Inclusion and Exclusion Criteria**

98 Healthy Individuals were included in the study. Persons with systemic illness such as diabetes
 99 mellitus, hypertension, hyperthyroidism, gigantism, dwarfism, individuals taking antibiotic
 100 treatment, any lesion on tongue, developmental and acquired, history of habits, such as smoking
 101 and tobacco chewing were excluded from the study.

102 **2.4 Data collection procedures**

103 The examination of the tongue was carried out after prior cleaning with abundant rinsing of the
 104 oral cavity. The purpose of the direct examination of the tongue was to emphasize morphological
 105 features. The participants sat relaxed with their face properly illuminated and their head positions
 106 in Frankfurt's horizontal plane. Participants were asked to protrude their tongue up to maximum
 107 in a relaxed position and not suddenly so as to prevent a marked contraction of the striated lingual
 108 muscles, which could alter the morphological characteristics. Environmental and lighting
 109 conditions were suitable for data collection. A professional Canon (EOS 1200 D, China,18.0 mega
 110 pixels) digital camera placed on a tripod was used to take images of participants from a
 111 predetermined distance. The participants were then evaluated for the morphological
 112 characteristics of the tongue. In this study, six morphological characteristics were taken into
 113 consideration; shape, colour, apex, margin, pattern of tongue surface and fissure. The distance

between the participant and the camera was kept at roughly 20 cm. This was the closest distance at which the features of the image could be taken clearly without compromising the quality and clarity. The shape of the tongue was assessed with three reference parameters; The points where the protruded tongue image contacts the commissures of the lip and the apex of the tongue on maximum protrusion. The width of the tongue was measured with the help of two reference parameters – the points where the tongue contacts the commissures of the lip as shown in Figure 1B. The length of the tongue visible on maximum protrusion was measured with the help of the three reference parameters – the line joining the apex perpendicularly to the line connecting the points of contact on the commissure of the lip (Jayan *et al.* 2019) as shown in Figure 1A. Image J software (Wayne Rasband, National Institutes of health, Bethesda, Maryland, U.S.A) was used to measure the length (Figure 1A) and width (Figure 1B) of the tongue.

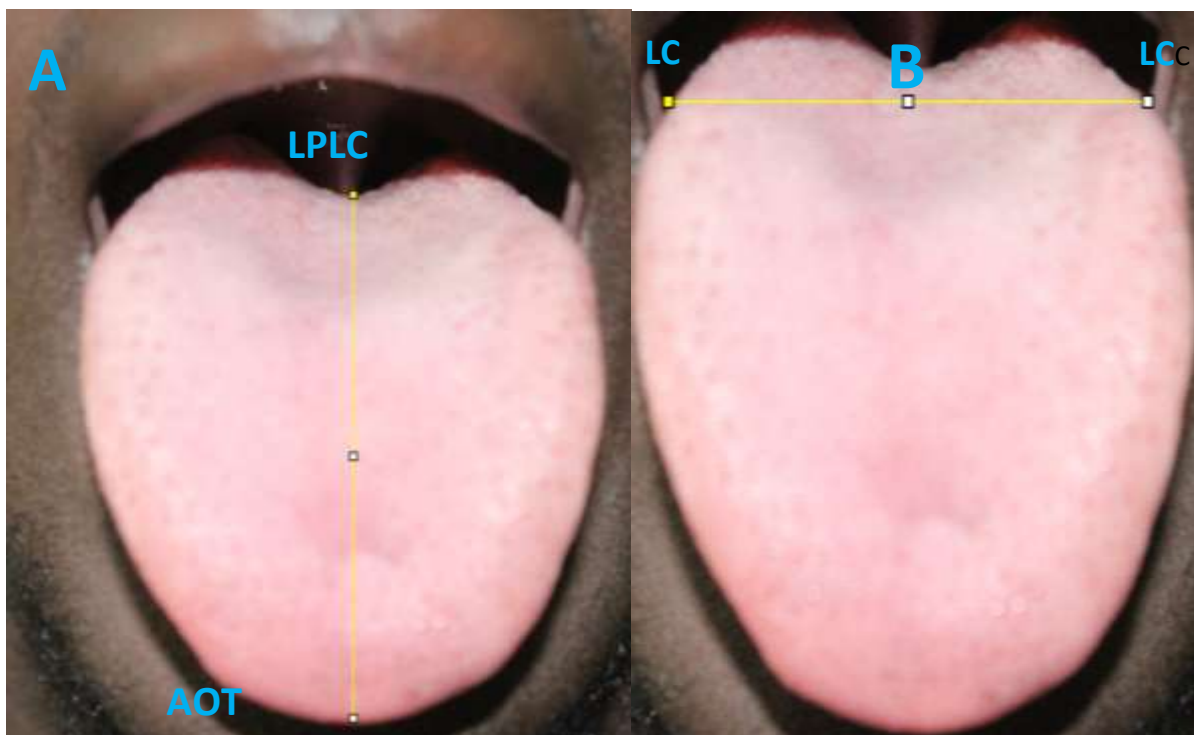


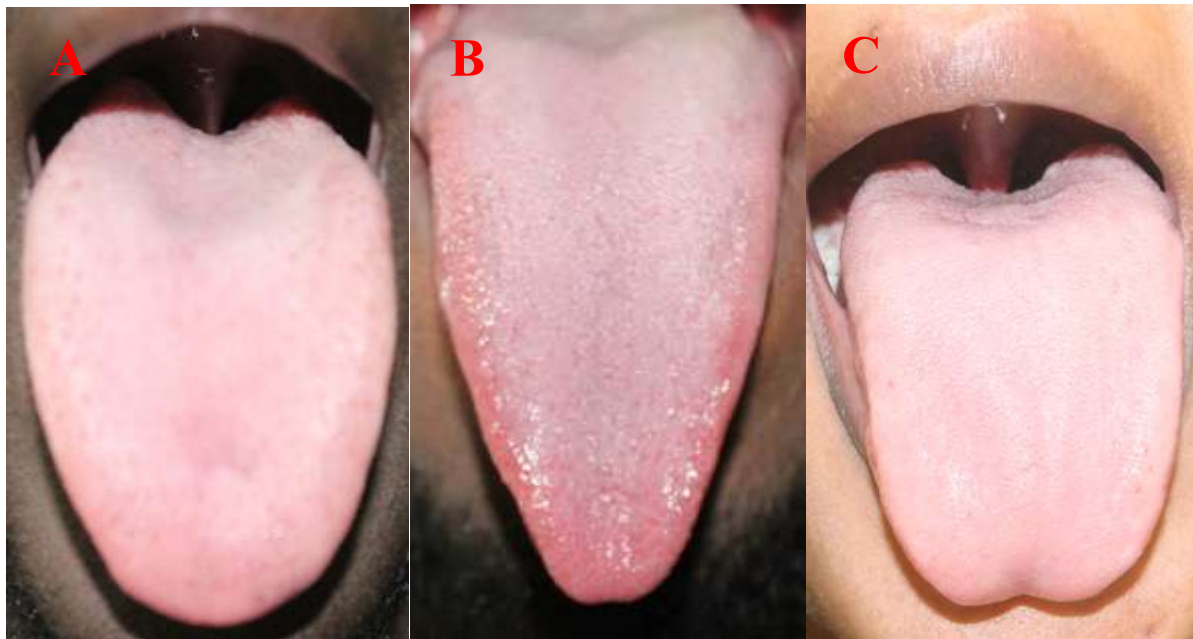
Figure 1: A photograph showing how the length and width of the tongue was measured with Image J

128

129

130 To assess the reproducibility and precision of the measurements, twenty randomly chosen tongue
131 images were measured by two observers, and the results were tested using the intraclass correlation
132 coefficient (ICC), and the average measure was 0.79, indicative of good reliability. For intra-
133 observer reliability, the two sets of measurements were compared by paired t-test wherein no
134 significant difference was found in the mean values. Tongue prints were classified as U (Figure
135 2A), V (Figure 2B) or W (Bifid) (Figure 2C) as presented in Figure 2.

136



137

138 **Figure 2:** A photograph of U, V and W shaped tongues (Right – Left) (x 0.5)

139

140

141 The colour of the tongue was classified as pale pink (Figure 3B) if the colour of the tongue is soft,
142 light pastel with low saturation and high lightness whereas reddish pink (Figure 3A) if the tongue
143 colour is deep, warm and highly saturated shade closer to red.

144



145

146 **Figure 3:** A photograph of pinkish-red and pale pink colour types of tongue (Right – Left) (x 0.5)

147

148 The apices of the tongue was classified as either pointed or blunt. Pointed tongue apex are narrow
149 and taper to a point (Figure 4A) whereas blunt apices were larger or flatter (Figure 4B)

150



Figure 4: A photograph of pointed and blunt apex of tongue of participants (Right – Left) (x 0.5)

The margin of the tongue was classified as smooth, scalloped or ulcerated. Smooth tongue margin has shiny, red or pink with glossy appearance (Figure 5A). Scalloped tongue margin has wavy, depressed edges (Figure 5B) whereas ulcerated tongue margin has broken, patches around the tongue (Figure 5C).



Figure 5: A photograph of smooth, ulcerated and scalloped tongue margin of participants (Right – Left) (x 0.5)

173

174 The pattern of the tongue was classified as geographic, physiologic or scrotal.

175 **Geographic tongue:** Irregular, map-like, smooth red patches on the top or sides of the tongue,
176 often with raised white or yellowish borders (Figure 6A).

177 **Physiologic tongue:** It is generally pinkish-red, moist, and symmetrical, featuring a slightly
178 rough, papillary dorsal surface and a smoother ventral surface (Figure 6B)

179 **Scrotal tongue:** It is characterized by deep grooves, fissures, or furrows on the top (dorsal)
180 surface and sides of the tongue (Figure 6C)

181



182

183 **Figure 6:** A photograph of geographic, physiologic and ulcerated tongue pattern of participants
184 (Right – Left) (x 0.5)

185

The fissures of the tongue were visualised and classified as single fissure and absence of fissure.

Fissures are characterized by deep furrows, fractures, or grooves (2–6 mm) on the tongue's upper surface that frequently radiate from a central fissure (Figure 7B)

Absence of fissures on a tongue: The dorsum (top surface) is pink, smooth, and uniformly textured; it lacks any deep furrows, fissures, or grooves (Figure 7A).



Figure 7: A photograph of absence of fissure and single fissure of participants (Right – Left) (x 0.5)

3.2.6 DATA ANALYSIS

Statistical analyses were carried out using IBM SPSS 26.00 version, Inc., Chicago, IL, U.S.A. The mean, standard deviation, range, and standard error were obtained for each of the measurements. To assess the significance of sex and side differences, an independent t-test was applied. Pearson's chi-square test was used to assess the association between sex and the morphological characteristics of the tongue. Receiver Operating Characteristic Curve analysis was used to determine how well the tongue dimensions can distinguish between both sexes. The level of statistical significance was set at $p < 0.05$.

3.3 RESULTS

3.3.1 MORPHOLOGICAL CHARACTERISTICS OF THE TONGUE PRINT

A cross-tabulation analysis was performed to examine the relationship between sex (male and female) and Shape of Tongue (U, V, and W). Although both sexes showed predominance of U-shaped tongue 281(80.3%), among males, the majority were classified under U-shaped Tongue, 110 (78.6), followed by V-shaped 18(12.9), then W-shaped tongue 12(8.6). A similar pattern was observed among females. There was no statistically significant association between sex and shape of tongue χ^2 (2, N=350) = 2.72, p = 0.25) (Table 1). The likelihood test (p = 0.257) corroborated this finding above the threshold for statistical significance. There was a weak association between sex and the shape of the tongue (Cramer V = 0.25, Phi = 0.32). The commonest margin of tongue was smooth, 207(59.1%), whereas the scalloped tongue margin was 136 (38.9%). The least margin of the tongue was ulcerated, 7(2%). Margin of tongue cannot be used to distinguish between male and female because there was no significant association between sex and margin of tongue (χ^2 (2, N=350) = 1.09 p = 0.58) (Table 1). Majority of the participants, 190(54.3%) were physiologic, 136(38.9%) recorded geographic pattern and the least tongue surface pattern of 24(6.8%) was scrotal. The physiologic pattern of the tongue surface was the commonest among both sexes. The pattern of tongue could not be used to distinguish between males and females since there was no association between sex and pattern of tongue surface (χ^2 (2, N=350) = 3.86, p = 0.28) (Table 1).

Table 1: Morphological Characteristics of Tongue Stratified by Sex

Variable	Sex	Morphological Characteristics			Pearson's		
		(n%)	(n%)	(n%)	df	χ^2	p-Value
Shape of Tongue		U	V	W			
	M	110(78.6)	18(12.9)	12(8.6)	2	2.72	0.25
	F	171(81.4)	30(14.3)	9(12.6)			
	Total	281(80.3)	48(13.7)	21(6)			
Margin of Tongue		Scalloped	Smooth	Ulcerated			
	M	56(40)	80(57.1)	4(2.8)	2	1.09	0.58
	F	80(38.1)	127(60.5)	3(1.4)			
	Total	136(38.9)	207(59.1)	7(2)			
Pattern of Tongue Surface		Geographic	Physiologic	Scrotal			
	M	53(37.9)	74(52.9)	13(8.6)	2	3.86	0.28
	F	83(39.5)	116(55.2)	11(3.8)			
	Total	136(38.9)	190(54.3)	24(6.8)			

Pale pink was the commonest colour of the tongue 235(67.1%), whereas 115(32.9%) had reddish pink tongue. Majority of females, 141(67.1%) had pale pink tongue whereas 69 (32.9%) males had reddish pink tongue. The apex of the tongue of participants was predominantly blunt, 307 (87.7%). Only 43(12.3%) had pointed tongue apex (Table 2). Pearson's chi-square Test of association indicated that, there was no significant association between the two variables, χ^2 (2, N=350) = 2.78, p = 0.25. Most of the participants, 320 (91.4%) had no fissure on the tongue for both sexes. Only 30 (8.6%) participants had a single fissure. There was no significant association between sex and presence or absence of fissure χ^2 (1, N=350) = 0.61, p = 0.44 (Table 2).

Table 2: Morphological Characteristics of Tongue Stratified by Sex

Variable	Sex	Morphological characteristics		df	Pearson's χ^2	p-Value
Colour of Tongue		Pale Pink (%)	Reddish Pink (%)			
	M	94(67.1)	46(32.9)	1	0.00	1.00
	F	141(67.1)	69(32.9)			
	Total	235(67.1)	115(32.9)			
Apex of Tongue		Blunt (%)	Pointed (%)			
	M	122(87.1)	18(17.2)	1	0.71	0.79
	F	185(88.1)	25(11.9)			
	Total	307(87.7)	43(12.3)			
Fissure of Tongue		No fissure (%)	Single fissure (%)			
	M	126 (90)	14 (10)	1	0.61	0.44
	F	194(92.4)	16 (18)			
	Total	320(91.4)	30(8.6)			

3.3.2 TONGUE DIMENSIONS OF PARTICIPANTS

The mean value for the length of the tongue of males was numerically higher than that of females but was not statistically different between the sexes. The width of the tongue of the females was numerically higher than that of the males but there was no reverse sexual dimorphism (Table 3).

Table 3: Descriptive statistics of tongue dimensions stratified by sex

Parameter	Sex	N	Range (mm)	Mean $\pm$ SD (mm)	t	p-Value
Tongue Length	M	140	20.21 – 89.26	58.51 $\pm$ 14.67	1.21	0.23
	F	210	21.74 – 99.00	56.50 $\pm$ 15.52		
Tongue Breadth	M	140	29.49 – 84.75	52.83 $\pm$ 11.79	-1.65	0.10
	F	210	27.17 – 104.29	55.32 $\pm$ 14.97		

3.3.3 SEX DETERMINATION OF TONGUE USING BINARY LOGISTIC REGRESSION

Binary logistic formulae were derived using the model: $\text{Log}(p/1-p) = a + bx$, where $\text{Log}(p/1-p)$ is the Logarithm of probability, “a” represents the regression constant, b represents the coefficient of regression, and x represents the independent variable. Binary logistic regression analysis was conducted to assess the ability of Length and width of tongue to predict sex. Each parameter was entered individually to predict sex (male = 1, female = 0). The omnibus test of model coefficients showed that the binary logistic regression model was statistically significant ($\chi^2(2) = 13.68$, $p = 0.001$), demonstrating that the inclusion of Length and Width of tongue significantly improved the prediction of sex compared with an intercept-only model. Tongue length was a significant predictor of sex ($B = 0.03$, $SE = 0.01$, $Wald = 10.12$, $p = 0.001$), Tongue breadth was a significant predictor of sex ($B = -0.04$, $SE = 0.01$, $Wald = 11.25$, $p = 0.001$) (Table 4). Although the models were statistically significant, the included predictors only explained a small percentage of the variance in sex, as indicated by the Nagelkerke R^2 value of 0.052. Additionally, unsatisfactory model fit is shown by the significant Hosmer–Lemeshow test ($p = 0.041$), which implies that the predicted probability did not sufficiently match the observed outcomes. The model correctly classified 22.9% of males and 91.0% of females with an overall accuracy of 63.7%.

300

301

302 **Table 4: Binary Logistic Regression Equations for sex prediction using Tongue length and**
 303 **breadth**

Predictor	B	S.E	Wald	P-value	Exp(B)	df	95% C.I	
							Lower	Upper
Tongue Length (TL)	0.03	0.01	10.12	< 0.01	1.03	1	1.01	1.05
Tongue Breadth (TB)	-0.04	0.01	11.25	< 0.01	0.96	1	0.94	0.98
Constant (Intercept)	-0.18	0.48	0.13	0.72	0.84	1		

304

305 **Table 5: Classification Accuracy of Binary Logistic Regression Models for Tongue length**
 306 **and width**

307

Predictor	Correctly classified males (%)	Correctly classified females (%)	Overall correctly (%)
Tongue Length and width	22.9	91.0	63.7

308

309

310

311 **3.3.4 SENSITIVITY AND SPECIFICITY OF MODEL OF TONGUE DIMENSIONS** 312 **USING RECEIVING OPERATING CHARACTERISTICS CURVE (ROC) AND** 313 **AREA UNDER THE CURVE (AUC)**

314 Receiver Operating Characteristics (ROC) curve analysis and Area under the curve (AUC) were used to
 315 determine how well the tongue dimensions could distinguish between both sexes. ROC curve revealed that
 316 tongue length (AUC = 0.456, 95% CI: 0.395–0.518, p = 0.165) and tongue width (AUC = 0.543, 95% CI:
 317 0.483–0.604, p = 0.169) exhibited poor and non-significant discriminative ability for sex determination.

Although tongue width showed slightly better performance than tongue length, neither parameter achieved clinically meaningful sensitivity and specificity, and no optimal cut-off values were identified. Therefore, both variables are inadequate predictors of sex in this population.

Table 6: Sensitivity and Specificity of Tongue dimensions

Variable	AUC	S.E	P-value	Confidence Interval	
				Lower	Upper
Tongue Length	0.456	0.031	0.165	0.395	0.518
Tongue width	0.543	0.031	0.169	0.483	0.604

Figure 6, shows a ROC curve; Y axis represents true positives/ sensitivity whereas x axis shows false positives or specificity. The curve displays tongue length and width with a reference line between the two dimensions.

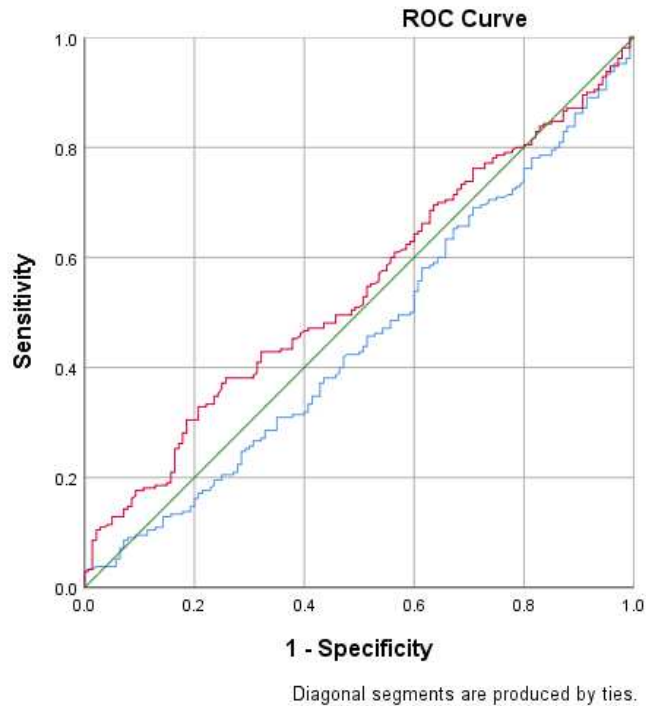


Figure 6: A ROC curve showing the sensitivity and specificity of tongue dimensions

3.5 DISCUSSION

In the present study, the U-shape tongue was the most predominant for the total population, followed by the V-shape. The least common type was the W-shape. This aligns with the findings of Sreepradha *et al.* (2019) in India, with a similar report of the U-shape being the most common among the total sample. Tongue morphology is influenced by genetic predispositions through developmental genes and intrinsic muscle architecture. Over time, a U-shaped form of tongue is reinforced by a larger, rounded anterior contour that is mechanically efficient and stable due to tongue posture, pressure against the teeth, and prolonged use (speaking, swallowing, mastication) (Mehra *et al.*, 2025). The U and V-shaped tongues were predominant in females compared to those of males. This is consistent with the findings of several authors in Nepal, India, and Malaysia (Chaulagain *et al.*, 2022; Hingad *et al.*, 2024; Venkatesh *et al.*, 2019). However, the findings of the present study contradict the results of several other investigators in India on the predominance of U and V -shaped tongues in males (Abarnalingam *et al.* 2019; Bhargava *et al.* 2022; Desai and Christopher 2019; Garg *et al.*, 2020; Jeddy *et al.*, 2017). Age, sex, and weight all affect tongue muscle volumes, which result in structural variations, including shape (Hingad *et al.*, 2024; Scendoni *et al.*, 2023). In a similar study in India, Jayan *et al.* (2019) also found that the males exhibited the U-shape more frequently than females. Females were more likely than males to have tongues with a V shape (Avhad, 2021). Avhad (2021) attributed the predominance of V shape in females to smaller mandible size compared to males. On the contrary, a study by Panchbhai and Parida (2021) in India, reported that more females were found to have the U shape and W (bifid tongue), whereas none of the sexes exhibited the V shape.

Gawali *et al.* (2024) in India reported that the U shape of the tongue also showed some correlation with blood groups in certain populations, with specific blood groups more likely to have U-shaped

tongues in either sex. In their study, the O⁺ females had a U-shaped tongue, whereas the B⁺ males recorded U-shaped tongues. Pale pink was the most common tongue colour. Pale pink colour is often seen as a sign of a healthy tongue and is usually accompanied by small nodules on the surface called papillae. A study by Horzov *et al.* (2021), on the colour of tongue among patients with different levels of disease severity found that 64.29% of those with mild disease had a pale pink tongue, whereas red and dark red were more prevalent in moderate to severe COVID-19 cases. In contrast, patients with severe illness more often had crimson or burgundy tongues, with fewer cases showing pale pink. The study highlights that tongue colour, including pale pink, can be linked to health conditions, especially the severity of illness. Similarly, the most common tongue colour among young people, according to Hingad *et al.* (2024) was pink. A study by Kainuma *et al.* (2015), on the Okinawan population in Japan reported that pale pink tongue colours were associated with certain gastrointestinal disorders, including erosive gastritis and oesophageal hernia. This suggests that tongue colour can represent sudden changes in the mucosa of the stomach. The present study, reported no significant association between the colour of tongue and sex. This is consistent with what was documented by Hingad *et al.* (2024) in India.

The present study recorded smooth margin of the tongue as the commonest. Smooth margin was more prevalent in females than in males. This agrees with the findings of Avhad (2021) in India. Scalloped borders were more common in males than females. This is in line with the findings of several authors in India (Chaulagain *et al.*, 2022; Avhad, 2021; Vijay *et al.*, 2019). Sreepradha *et al.* (2019) reported that, scalloped borders were formed when tooth indentations are created around the edges of the tongue. It is caused by the negative pressure in the oral cavity, which leads to parafunctional behaviours such as tongue thrusting, bruxism, cheek sucking, and sleep disturbances. There was no significant association between the margin of the tongue and sex.

Physiologic tongue surface was the most predominant in the present study. This contradicts earlier studies in India and Romania that reported that geographic and scrotal tongues were characteristic of females (Johnson, 2018; Stefanescu *et al.*, 2014). Vijay *et al.* (2019), in India also reported that geographic tongue was more common in males than females.

Absence of fissure in the present study, on the tongue was very common for both sexes. This agrees with previous studies done by Chaulagain *et al.* (2022) in India, which documented high prevalence of absence of fissures on their tongues. Single fissure was common among females than among males. This agrees with what was reported by Sreepradha *et al.* (2019). However, it contradicts with the findings of Avhad (2021) who recorded more single fissures in males than females in Satara district, Maharashtra, in India. The risk factors for fissured tongue includes; diabetes mellitus, being a male and usage of smokeless tobacco. Single fissure is more common in males and increases with age, reaching its peak in the 20-40 age range. There was no significant association between tongue fissure and sex. This is consistent with the similar findings reported by Bhat *et al.* (2018) and Mathew *et al.* (2017).

The apex of the tongue of participants of the present study was predominantly blunt. Females recorded the highest incidence of blunt apex tongue, whereas the pointed apex of the tongue was more common in males than females. In contrast to the findings of the present study, a sharp apex was more common in females and a septate/blunt apex in males (Vijay *et al.*, 2019). The present study recorded no significant association between the apex of the tongue and sex. This agrees with what Hingad *et al.* (2024) reported in India. The length of the tongue was numerically higher in males whereas the width of the tongue was numerically higher in females. However, none of the dimensions was sexually dimorphic. This agrees with the findings of several previous studies in India and Brazil on African and European populations (Anand *et al.*, 2019; Beghini *et al.*, 2017; Bhargava *et al.*, 2022; Mehra *et al.*, 2025). Conversely, Singh *et al.* (2020) reported that, the posterior tongue width of an Indian population

was wider in males than females. The length and width of the tongue were used to formulate models using binary logistic regression. The overall prediction accuracy of the model was 63.7%. This moderate accuracy indicates that tongue dimensions alone may not be sufficiently reliable as a standalone method for sex determination and should ideally be used in conjunction with other skeletal or dental indicators. Measurements are not sufficiently discriminative for individual-level sex estimation, but may contribute as one low-weight component in a multivariate craniofacial profile. The model has not been validated for casework. Singh *et al.* (2020) reported that, prediction models based on tongue measurements was frequently sex bias. The physical differences (length and width) may assist classification models, although male prediction accuracy is lower than female prediction accuracy, indicating the difficulties of attaining balanced categorization (Paul et al., 2024; Rana et al., 2024). Some research works have found that logistic regression models including tongue dimensions can be successful for sex categorization, underlining the potential of lingual morphometrics as forensic identifiers. This has been linked to small physical variations in females that may be more prominent or persistent than in males, as well as the effect of sample size and population-specific features. Tongue shape categories have also been connected to sex, but do not consistently increase model accuracy. Although tongue breadth and length can influence sex determination models, stated prediction accuracy was frequently modest and occasionally biased in favour of female prediction accuracy. The ROC curve analysis revealed that both tongue length and width, were poor predictors of sex, with no statistically significant discriminatory capacity. To enhance balanced sex prediction ability, the best studies combine tongue morphometrics with additional oral or craniofacial data. Length and width of tongue combined predictive and explanatory power was constrained. This emphasizes the multifaceted character of sexual dimorphism and the necessity of using multivariate techniques or other odontometric variables to increase the accuracy of sex estimation.

LIMITATIONS

- Convenience sampling of 350 volunteers (140 males, 210 females) introduces potential selection bias. The population of males (140) to females (210) in the present study shows sex imbalance. The ratio of males to females was disproportional inferencing that the sample size was sex bias since which may affect the prediction accuracies of the tongue dimensions.
- The study was carried out on undergraduate students in a university. A University-based population may limit full generalizability of the results of the study. This implies that the outcome of the study cannot be used to represent the wider Ghanaian population.
- Participants were limited to an age range of 18–42 years, with a mean age in the early twenties. This excludes adolescents, older adults, and elderly populations, thereby limiting the applicability of the findings across the full lifespan commonly encountered in forensic investigations.

3.5 CONCLUSION

U-shaped tongue, pale pink, Smooth tongue margin, physiologic tongue and absence of fissure on the tongue was very common for both sexes. The models formulated by length and width of the tongue using binary logistic regression were sexually biased and had poor classification performance. The model is exploratory and of limited forensic utility. Receiver Operating Characteristics exhibited poor and non-significant discriminative ability for sex determination. Digital images of the tongue dimensions may not be sufficiently reliable as a standalone method for sex determination and should ideally be used in conjunction with other skeletal or dental indicators.

450

451

452 **ABBREVIATIONS**

453	%	Percentage
454	a	regression constant,
455	AOT	Apex of tongue
456	b	co-efficient of regression, and
457	CHRPE	Committee on Human Research, Publications and Ethics
458	CI	Confidence Interval
459	df	Degree of freedom
460	F	Female
461	IBM	International Business Management
462	ICC:	Intraclass correlation coefficient
463	KNUST	Kwame Nkrumah University of Science and Technology
464	LC	Labial Commissure
465	Log (p/1-p)	Logarithm of probability,
466	LPLC	Line perpendicular to labial commissure
467	M	Male
468	N	Number
469	n	Sample size
470	P	Probability
471	S.E	Standard Error
472	SD	Standard Deviation
473	SPSS	Statistical Package for Social Scientist
474	t	t statistics
475	TB	Tongue Breadth
476	TL	Tongue Length
477	x	represents the independent variable

478 χ^2 Chi-square test

479

480

481

482

483

484

485

486

487

488

489

490

491

492

493

494

495

496

REFERENCES

- Adam, A. M. (2020).** Sample Size Determination in Survey Research. *Journal of Scientific Research and Reports*, **26**(5), 90-97.
- Abarnalingam, S., Desai, D. and Christopher, G. S. (2019).** Comparison of lip prints, rugae pattern. *International Journal of Innovative Science Research Technology*, **4**, 1182–1187.
- Anand, P., Raju, M. S., Chandra, S. and Kumar, D. (2019).** Gender divergence in dimensions of tongue: A morphometric study. *International Journal of Dental Science and Innovative Research*. www.ijdsir.com
- Avhad, S. (2021).** Sexual Dimorphism from Visual Examination of Tongue in Satara District. *International Journal of Forensic Science and Pathology*, 441–445.
<https://doi.org/10.19070/2332-287X-2100093>
- Beghini, M., Pereira, T. L., Montes, J. M. C., De Moura, D. V., Dezem, T. U., Da Silva, H. R., Rocha, D. B. and Pereire, S. A. D. (2017).** Morphometric Analysis of Tongue in Individuals of European and African Ancestry. *Journal of Forensic Investigation*, **5**(1), 1–5.
<https://doi.org/10.13188/2330-0396.1000038>
- Bhargava, A., Saigal, S., Danish Rehan, A. and Kausar, T. (2019).** Saudi Journal of Oral and Dental Research Abbreviated Key Title: Saudi Journal of Oral Dental Reserch ISSN.
<https://doi.org/10.21276/sjodr.2019.4.3.9>
- Chaulagain, R., Baral, S., Kandel, S., Agrawal, A. and Gautam, A. (2022).** Variations in Shape of Tongue among Students attending Chitwan Medical College. *Nepal Medical Journal*, **5**(2), 39–43. <https://doi.org/10.37080/NMJ.143>

Desai, D. and Christopher, G. S. (2019). Comparison of Lip Prints, Rugae Pattern and Tongue Prints among Karnataka, Kerala and Tamil Nadu Population – A Short Study. *International Journal of Innovative Science and Research Technology*, **4**(7), 1182–118

Garg, K., Sachdev, R., Shwetam, S., Saxena, S., Mehrotra, V. and Srivastava, A. (2020). Evaluation of morphological characteristic and varieties of tongue prints for personal identification in Kanpur communities: An impression-based analysis. *The Saint's International Dental Journal*, **4**(1), 54. https://doi.org/10.4103/SIDJ.SIDJ_19_20

Gawali, N., Bhargava, A., Saigal, S., Khelkar, P., Mangulkar, A. P. and Fukate, C. A. (2024). Correlation and Comparison of Tongue Print and Lip Print with Blood Group among Dental Students of Jharkhand. *Journal of Pharmacy and Bioallied Sciences*, **16**, S2049–S2052. https://doi.org/10.4103/jpbs.jpbs_17_24

Hingad, N., Kumar, G., Singh, K., Mahajan, A., Pal Singh, M. and Singh Gambhir, R. (2024). Tongue print as a valuable biometric and forensic tool: A digital photographic study. *Nigeria Med J*, **65**(5), 673–681. <https://doi.org/10.60787/nmj-v65i3.530>

Horzov, L., Goncharuk-Khomyn, M., Hema-Bahyna, N., Yurzhenko, A. and Melnyk, V. (2021). Analysis of tongue color-associated features among patients with pcr-confirmed covid-19 infection in Ukraine. *Pesquisa Brasileira Em Odontopediatria Clinica Integrada*, **21**. <https://doi.org/10.1590/PBOCI.2021.109>

Jayan, L., Bharanidharan, R., Ramya, R., Priyadharsini, N. and Kumar, Ar. (2019). Tongue morphometry: Evaluation of morphological variations in ethnic Tamil population. *SRM Journal of Research in Dental Sciences*, **10**(3), 139.

Johnson, A. (2018). A Morphological Study of Tongue and its Role in Forensics Odontology. *Journal of Forensic Sciences and Criminal Investigation*, 7(5). <https://doi.org/10.19080/jfsci.2018.07.555723>

Kainuma, M., Furusyo, N., Urita, Y., Nagata, M., Ihara, T., Oji, T., Nakaguchi, T., Namiki, T., and Hayashi, J. (2015). The association between objective tongue color and endoscopic findings: Results from the Kyushu and Okinawa population study (KOPS). *BMC Complementary and Alternative Medicine*, 15(1). <https://doi.org/10.1186/s12906-015-0904-0>

Mehra, S., Saxena, S., Pansotra, S., Puri, J., Mohammed, K., Saha, S., Gupta, S. and Kumar, S. (2025). Correlation Between Tongue Morphology and Dental Arch Dimensions in Skeletal Class I and Class II Malocclusions: A Cephalometric Study. *Cureus*, 17(3), e80946. <https://doi.org/10.7759/CUREUS.80946>

Panchbhai, A. and Parida, R. (2021). Evaluation of human tongue morphology and tongue groove patterns to explore its potential as a forensic aid. *Annals of the Romanian Society for Cell Biology*, 25, 7164–7172. <http://annalsofrscb.ro>

Paul, S., C, R. P. and Mary Cherian, L. (2024). *Tongue prints: a novel tool for sex determination-A preliminary study using digital photography.*

Radhika, T., Jeddy, N. and Nithya, S. (2016). Tongue prints: A novel biometric and potential forensic tool. *Journal of Forensic Dental Sciences*, 8(3), 117. <https://doi.org/10.4103/0975-1475.195119>

Rana, P., Suresh, D., Sekhar, M. C., Sravanthi, Y. M. and Mehta, K. H. (2024). Patterns of identity: Lip prints, tongue prints and mandibular canine width as markers for gender

determination—A cross-sectional study. *Journal of Family Medicine and Primary Care*,
13(10), 4528. https://doi.org/10.4103/JFMPC.JFMPC_242_24

Rezaei, F., Safarzadeh, M., Mozafari, H. and Tavakoli, P. (2015). Prevalence of Geographic
tongue and Related Predisposing Factors in 7-18 Year-Old Students in Kermanshah, Iran 2014.
Global Journal of Health Science, **7**(5), 91–95. <https://doi.org/10.5539/gjhs.v7n5p91>

Singh, J., Singh, S., Saleem, M., Chandra, S., Lodhi, N. and Chang, C. P. (2020). Tongue
and its ties: Posterior tongue width in gender estimation – A forensic gratuity. *National Journal
of Maxillofacial Surgery*, **11**(1), 53. https://doi.org/10.4103/NJMS.NJMS_40_19

Sreepradha, C., Vaishali, M. R. and David, M. P. (2019). Tongue replica for personal
identification: A digital photographic study. *Journal of Indian Academy of Oral Medicine and
Radiology*, **31**(1), 57–61. https://doi.org/10.4103/jiaomr.jiaomr_59_19

Stefanescu, C. L., Popa, M. F. and Candea, L. S. (2014). Preliminary study on the tongue-
based forensic identification. *Romanian Journal of Legal Medicine*, **22**(4), 263–266.
<https://doi.org/10.4323/rjlm.2014.263>

Vijay, P., Sharma, S., Chandra, S., Pardhe, N., Singh, P., and Srivastava, Y. (2019). A
study on Evaluation of various tongue patterns in North Indian population and a working
classification system for these tongue print patterns. *International Healthcare Research
Journal*, **3**(2), 76–79. <https://www.academia.edu/download/100837302/355.pdf>

FIGURE/TABLE LEGENDS

FIGURE LEGENDS

Figure 1 legend: AOT: Apex of tongue; LC: Labial Commissure; LPLC: Line perpendicular to labial commissure

Figure 1: A photograph showing how the length and width of the tongue was measured with Image J

Figure 2 Legend: A (U -shaped Tongue), B(V-shaped Tongue) , C (W-shaped Tongue)

Figure 2: A photograph of U, V and W shaped tongues (Right – Left) (x 0.5)

Figure 1 legend: A (Pinkish red Tongue), B(Pale -pinkTongue)

Figure 3: A photograph of pinkish-red and pale pink colour types of tongue (Right – Left) (x 0.5)

Figure 4 legend: A (Pointed apex of tongue), B (Blunt apex of tongue)

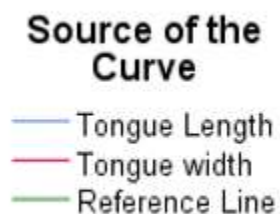
Figure 4: A photograph of pointed and blunt apex of tongue of participants (Right – Left) (x 0.5)

Figure 5 Legend: A(Smooth), B (Ulcerated), C (Scalloped)

Figure 5: A photograph of smooth, ulcerated and scalloped tongue margin of participants (Right – Left) (x 0.5)

Figure 6: A ROC curve showing the sensitivity and specificity of tongue dimensions

Figure Legend



602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629

TABLE LEGENDS

Table 1 Legend

M= male; F= Female; n=number; %= Percentage; p = probability, statistically significant difference ($p < 0.05$); Chi-square test(χ^2), $p<0.05$, statistically significant

Table 2 Legend

M= male; F= Female; N=Number; %= Percentage; p = probability, statistically significant difference ($p < 0.05$) Test used- Chi-square test, $p<0.05$, statistically significant

Table 3 Legend

N= Number; M= male; F= Female; SD= Standard Deviation; p = probability, statistically significant difference ($p < 0.05$); t = t-statistic

Table 4 Legend

S.E = Standard Error, p = probability, statistically significant difference ($p < 0.05$), CI = Confidence Interval; TL: Tongue Length; TB: Tongue Breadth

Table 5 Legend

% = Percentage

Table 6 Legend

AUC= Area under the curve; S.E = Standard Error; p = probability, statistically significant difference ($p < 0.05$)

DECLARATIONS

Ethics approval and consent to participate: This work was approved by the Committee on Human Research, Publication and Ethics of the School of Medical Sciences, Kwame Nkrumah University of Science and Technology, with reference number: CHRPE/AP/1153/25.

Participants read and signed the consent forms after the purpose of the research was explained to them.

Consent for publication: Participants were made aware that this research would be published

Funding: Not applicable

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [LISTOFTABLESRevised.docx](#)