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Original Article

Prediction of Nasolabial Distance using Thumbprint Ridge Density among the Hausa Population of Nigeria

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Abstract

This study aimed to determine the potentials of thumbprint ridge count in prediction of nasolabial facial distances among the Hausa population of Nigeria.

This is a cross-sectional study in which a total of 457 subjects participated. Plain fingerprints were captured using a fingerprint scanner. Three areas, ulnar, radial and proximal were defined for determination of ridge counts. A photographic method was used to capture the facial images. Pearson's correlation analysis was used to measure the linear dependence between thumbprint ridge density and Nasolabial distances. Stepwise linear multiple regression analysis was used to predict nasolabial distances from thumbprint ridge density. SPSS statistical software version 20 was used for the statistical analysis and a p-value of < 0.05 was set as a level of significance.

Results showed that in males left proximal ridge count correlates negatively with nasal length, philtrum length, upper lip length and mouth width. The upper lip length and nasal width correlate negatively with left ulnar ridge count and right radial ridge counts, respectively. A positive correlation was observed between ulnar ridge count with nasal length and lower vermilion width. In females, a positive correlation was observed only between lower vermilion width and left proximal ridge counts. Left proximal ridge counts predict most of the nasolabial distances in

Keywords: Forensic Science, Ridge Density, Nasolabial Region, Prediction, Hausa Ethnic Group.

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males. In females, only the left proximal ridge counts showed potential in the prediction of facial distances.

The study concluded that the thumbprint correlates with facial distances of the nasolabial region. The proximal part of the thumbprint may respond to the same instruction in utero with the lower part of the face, hence leading to the prediction of nasolabial facial distances from the proximal ridge counts among the Hausa population of Nigeria.

التنبؤ بالأطوال الأنفية والشفوية باستخدام كثافة (تكدس) نتوءات بصمة الإبهام لدى سكان الهوسا في نيجيريا.

المستخلص

تهدف هذه الدراسة إلى تحديد إمكانية التنبؤ بالأطوال الأنفية والشفوية في الوجه لدى سكان الهوسا في نيجيريا باستخدام عدد نتوءات الإبهام لديهم.

شارك في هذه الدراسة المقطعية (Cross-sectional study) ما مجموعه 457 شخص. حيث أُخذت بصمات سطحية للأصابع باستخدام الماسح الضوئي، وقد تم تعريف ثلاثة مناطق في البصمة وهي منطقة الزندي ومنطقة الكعبري والمنطقة السفلى، وذلك لتحديد عدد النتوءات في كل منطقة. استُخدمت تقنية التصوير الفوتوغرافي لالتقاط صورة الوجه. كما استُخدم تحليل ارتباط بيرسون لقياس العلاقة الخطية بين كثافة نتوءات بصمة الإبهام وطول الأنف والشِّفة في الوجه. حيث استخدم تحليل الانحدار المتعدد الخطي المتدرج لحساب المسافات الأنفية والشفوية وذلك من كثافة نتوءات بصمة الإبهام. تم استخدام النسخة 20 من البرنامج الإحصائي SPSS وقد اعتمدت قيمة $p< 0.05$ لمستوى الدلالة الاحصائي.

أظهرت النتائج عند الذكور أن عدد النتوءات في المنطقة السفلية اليسرى يتناسب عكسياً مع كل من طول الأنف، وطول النثرة (الفرجة ما بين الشاربين تحت وترة الأنف)، وطول الشفة العليا وعرض الفم. إن طول الشفة العليا وعرض الأنف يتناسبان عكسيا مع عدد من النتوءات في المنطقة الزندية اليسرى ، وعدد النتوءات في المنطقة الكعبرية اليمنى. وقد لوحظ التناسب الطردي بين عدد النتوءات في المنطقة الزندية و طول الأنف وعرض الشفة السفلية.

أما عند الإناث فقد لوحظ وجود تناسب طردي فقط بين عدد النتوءات في المنطقة الزندية اليسرى وعرض الشفة السفلية. يمكن التنبؤ بالأطوال الأنفية والشفوية عند الذكور من خلال عدد النتوءات في المنطقة السفلية اليسرى. أما عند الإناث فإن عدد النتوءات في المنطقة السفلية اليسرى فقط أظهر إمكانية التنبؤ بأطوال الوجه.

إن الدراسة استنتجت أن بصمة الإبهام تتناسب مع أطوال الوجه في منطقة الأنف والشفة. إن المنطقة السفلى من بصمة الإبهام قد تستجيب في الرحم للتعليمات نفسها مع الجزء السفلي من الوجه، ومن ثم فإنه يمكن التنبؤ بالأطوال الأنفية-الشفوية للوجه من خلال عدد النتوءات في المنطقة السفلية من بصمات الإبهام بين السكان الهوسا.

الكلمات المفتاحية: علوم الأدلة الجنائية ، كثافة النتوءات، المنطقة الأنفية-الشفوية، التنبؤ، مجموعة الهوسا العرقية.

1. Introduction

The crucial events for the formation of the epidermal ridge pattern take place from the 10th to 16th weeks of pregnancy [1]. The surface patterns of the ridges become well pronounced at the 16th week of intra uterine life [1, 2]. Development of the nasolabial region occurs between the 4th to 10th weeks of fetal development, and by the 12th week the formation of the nasal septum is completed. Beyond the 12th week the epithelial plug in the nasal cavity dissolves, and at the mid-16th week, the nasal passages are complete and open [3]. Due to developmental overlap between fingerprint formation and nasolabial facial formation, there is the possibility of sharing common genetic factors that interplay between the two parts [4].

Some level of association between fingerprint patterns and facial proportions was established in previous studies, which highlighted the need for further studies that may ex-

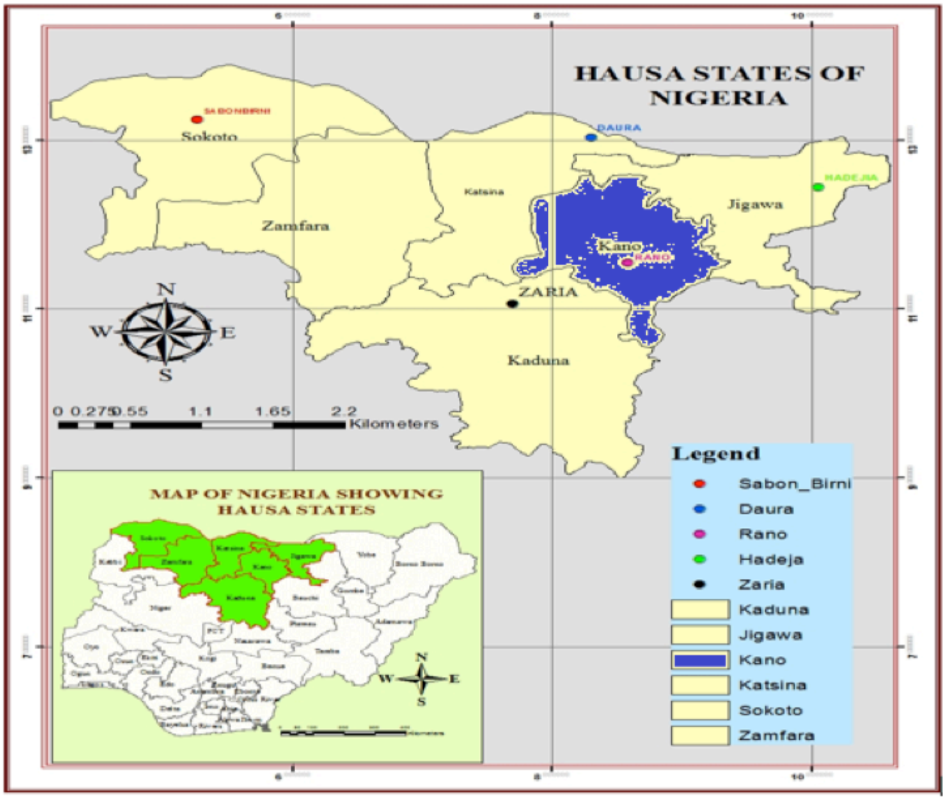

Figure 1- *Map of Hausa states of Nigeria showing the location of the study area (Kano).*

plain more of this relationship beyond qualitative results in order to develop a more robust quantitative approach [4]. Previous studies also established the relationship between dermatoglyphics and cleft palate (nasolabial region) [5], Down's syndrome [6], schizophrenia [7], apert syndrome [8], and diabetes [9]. This indicates that several disease conditions are associated with dermatoglyphics; hence, there is a need to define the specific region of fingerprints that may explain the possible risk of developmental anomalies in the nasolabial region.

In the field of forensic science and law enforcement, fingerprints are an important feature in establishing identity. It was reported that the ridge density of a latent print left at the scene of a crime can be used to infer the sex of the suspect, helping the forensic expert to narrow down the criminal investigation toward suspects belonging to the most likely sex, and so minimizing the time and effort spent on each case [10, 11]. In the present study, another step was also taken to explore the facial features of an individual from his thumb print profiles. This will serve as an additional way of establishing identity as well as reducing the number of suspects under investigation.

The aim of the present study was to determine the relationship between the thumbprint ridge count and facial distances among the Hausa population of Nigeria. We also determined the potential of the thumbprint ridge count to aid in the prediction of facial distances in the same region.

2. Materials and Methods

2.1 Study population

The participants of this crosssectional study were recruited from the Hausa population of Kano State, Nigeria (Figure-1). Using random sampling methods, a total of 457 subjects comprising 343 males and 114 females participated in this study. The time and site of data collection

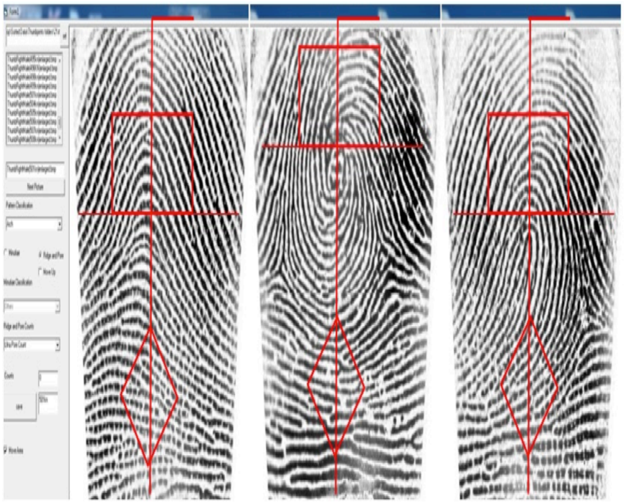

Figure 2- *Spaces (5mm x 5mm) on ulnar, radial and proximal areas of fingerprint for ridge density determination for three basic fingerprint patterns (loops, whorls and arches).*

were disclosed to the target population using pamphlets. The inclusion criteria included a genetic link to the Hausa population (through the grandfather), good general health, thumbs and faces free from any deformities or pathological changes. Only subjects within the age range of 18-25 years were considered. This was to minimize the effect of age on thumbprint and facial variables. Ethical approval was obtained from the ethical committee of Ahmadu Bello University, Teaching Hospital, Zaria, Faculty of Medicine (ABUTHZ/HREC/506/2015) and Kano state hospitals management board. Informed consent was also sought from the participants.

2.2 Determination of ridge density

Figure-2 indicates spaces (5mm x 5mm) on ulnar, radial and proximal areas of fingerprints for ridge density determination for three basic fingerprint patterns (loops, whorls and arches) [12]. The thumbprint was captured using a fingerprint scanner (Digital persona, China). For determination of ridge density in the ulnar, radial and proximal areas of the thumb, the method described by Acree, [13] and Gutiérrez-Redomero et al. [10] was used.

2.3 Facial image capturing, landmark identification and distance measurement

To obtain the photographs, each participant was asked to sit and look directly at the camera in front of them [14] with their head in the Broca's Natural Head Position [15]. The camera was placed on a tripod stand (WT3570, China) to standardize the distance (100 cm) between it and the participants [16, 17]. The images were saved to a computer and stored in JPEG format for processing and analysis.

Table-1 shows anatomical landmarks used for linear facial measurements. Seven anatomical landmarks were recognized from frontal view. Table-2 indicates linear facial dimensions with their corresponding landmarks. Eight facial linear distances were obtained as the distances between one anatomical landmark to another (Table-2) [18-20].

2.4 Measurement error and statistical analysis

To quantify precision, two sets of measurements of 30 randomly selected participants were taken and compared using technical error of measurement (TEM) [21]. This allowed assessment of random error. Absolute TEM $= \sqrt{\sum di^2/2n}$, where: Σd^2 = summation of deviations (The difference between the 1st and 2nd measurements) raised to the second power; n = number of volunteers measured; i = the number of deviations. The absolute TEM was expressed as percentages as follows; relative TEM = (Absolute TEM)/VAV× 100, where, VAV= Variable average value. This is the arithmetic mean of the mean between both measurements obtained (1st and 2nd measurements) from each volunteer for the same variable. The percentage scores exceeding 10% were deemed 'poor' [22, 23]. The intra-class correlation (ICC) was used to demonstrate the strength of the relationship (similarities) between first and second measurements. The values for the reliability coefficient (r) ranged from 0 to 1, where ICC < 0 indicated "no reliability", 0.6 to < 0.8 "substantial reliability" [24]. All

Table 1- *Anatomical landmarks used for linear facial measurements.*

SN	Landmarks	Abbreviation	Anatomical description
1	Alar	al	The most lateral point of the nasal wings
2	Chalion	ch	The outer most lateral point of the mouth
3	Labialeinferious	li	The midpoint of the lower vermilion line
4	Labialesuperious	ls	The midpoint of the upper vermilion line
5	Nasion	n	The point in the midline of both the nasal root and the nasofrontal suture, above the line that connects the two inner canthi
6	Stomium	sto	Mid-point of the mouth orifice
7	Subnasal	sn	The junction between the lower border of the nasal septum and the cutaneous portion of the upper lip, in the midline

Table 2- *Linear facial dimensions with their corresponding landmarks.*

SN	Facial linear distances	Landmarks
1	Nasal length	n - sn
2	Nasal width	al - al
3	Philtrum length	sn - ls
4	Upper lip length	sn - sto
5	Mouth height	ls - li
6	Mouth width	ch - ch
7	Upper vermilion width	ls - sto
8	Lower vermilion width	sto - li

variables in this study are within the acceptable measurement error.

Descriptive statistics of mean ± standard deviation (S.D.) were used to express the data; Pearson's correlation analysis was used for the relationship between thumbprint ridge density and facial linear dimensions. Stepwise multiple regression analysis was used to predict facial distances from thumbprint ridge density. SPSS statistical software version 20 was used for the statistical analysis and a *p*-value of < 0.05 was set as a level of significance.

3. Results

Table-3 shows the mean and standard deviation of the ridge counts of both left and right thumbs in male and

Table 3- *The ridge count of both left and right hand thumbs in male and female volunteers.*

Variables (mm)	Male	Female		
	Mean ± S.D.	Mean ± S.D.	Z-value	*p*-value
Right ulnar	10.06 ± 1.30	10.91 ± 1.62	-4.55	<0.001
Right radial	10.48 ± 1.52	10.18 ± 1.90	-1.083	0.279
Right proximal	9.78 ± 1.31	9.70 ± 1.65	-0.272	0.786
Left ulnar	10.42 ± 1.48	10.70 ± 1.51	-1.449	0.147
Left radial	10.65 ± 1.46	10.31 ± 1.70	-1.79	0.073
Left proximal	9.77 ± 1.13	9.17 ± 1.52	-2.961	0.003

Table 4- *Sexual dimorphism in facial linear dimensions and angles*.

Variables (mm)	Male	Female	t-test	*p*-value
	Mean ± S.D.	Mean ± S.D.		
Nasal length	40.67 ± 4.19	45.61 ± 4.40	-9.662	<0.001
Nasal width	40.68 ± 3.11	38.05 ± 3.11	7.12	<0.001
Philtrum length	12 ± 2.14	11.99 ± 1.77	0.027	0.978
Upper lip length	22.95 ± 2.28	21.59 ± 2.12	5.187	<0.001
Mouth height	23.79 ± 2.80	22.2 ± 2.62	4.93	<0.001
Mouth width	50.4 ± 4.15	47.3 ± 3.15	7.055	<0.001
Upper vermilium width	10.97 ± 1.47	9.62 ± 1.64	7.303	<0.001
Lower vermilium width	12.84 ± 2.14	12.59 ± 1.75	1.058	0.291

Table 5- *Correlation between thumbprint ridge count and nasolabial distances in male population of Hausa region*.

Facial dimensions (mm)	Right			Left		
	URC	RRC	PRC	URC	RRC	PRC
Nasal length	0.114*	-0.057	0.051	0.001	-0.049	-0.133*
Nasal width	-0.033	-0.102*	0.011	-0.087	-0.086	-0.091
Philtrum length	-0.04	-0.015	0.023	-0.078	0.012	-0.137*
Upper lip length	-0.018	-0.053	-0.004	-.0108*	-0.035	-0.126*
Mouth height	0.081	-0.032	0.068	-0.056	-0.084	0.037
Mouth width	-0.01	-0.051	0.071	-0.014	-0.042	-0.13*
Upper vermilion width	0.024	-0.05	-0.023	-0.053	-0.068	-0.013
Lower vermilion width	0.106*	-0.011	0.119*	-0.038	-0.073	0.055

*URC, ulnar ridge counts; RRC, radial ridge count; PRC, proximal ridge count; *p < 0.05*

female volunteers. It was observed that significant mean sex differences in ridge count occurred only in the right ulnar ridge count and left proximal ridge count. Comparison between the three areas of the thumb (ulnar, radial and proximal) showed lower ridge count in the proximal ridge counts in both sides and sexes. The highest count in males was observed in radial ridge count, whereas the ulnar ridge count was higher in females.

Table-4 indicates the mean and standard deviation of facial linear dimensions and angles in male and female volunteers. The entire facial linear distances showed significant sexual dimorphism except for philtrum length and lower vermilion width. In all the variables, males tended to have higher mean values, except for the nasal length (Table-4).

Table-5 shows the correlation between thumbprint

Table 6- *Correlation between thumbprint ridge count and nasolabial distances in female population of Hausa region.*

Facial dimensions (mm)	Right			Left		
	URC	RRC	PRC	URC	RRC	PRC
Upper facial height	0.071	-0.066	-0.038	0.05	0.096	-0.011
Nasal width	0.013	-0.083	-0.132	0.021	0.032	-0.029
Philtrum length	-0.056	0.065	-0.047	-0.008	-0.011	-0.048
Upper lip length	-0.044	0.073	0.043	-0.045	0.027	-0.072
Mouth height	0.028	-0.037	0.101	0.036	0.137	0.138
Mouth width	0.004	0.001	-0.085	0.064	0.134	0.05
Upper vermilion width	0.003	0.026	0.106	-0.047	0.049	-0.05
Lower vermilion width	0.039	-0.079	0.053	0.100	0.158	0.240*

*URC, ulnar ridge counts; RRC, radial ridge count; PRC, proximal ridge count; * p < 0.05*

Table 7- *Stepwise multiple regression analysis for prediction of facial distances from thumbprint ridge count.*

Sex	Side of the thumb	Models	R2	SEE	F-test	*p*-value
Male	Right Hand	Lower vermilion width = 0.23 (proximal ridge count) + 11.54	0.01500	2.51	5.48	0.02
	Left Hand	Nasal length = -0.58 (proximal ridge count) + 49.99	0.02121	5.34	7.00	0.009
		Nasal width = -0.36 (proximal ridge count) + 46.37	0.01417	3.99	4.64	0.032
		Philtrum length = -0.27 (proximal ridge count) + 14.51	0.02316	2.35	7.66	0.006
		Upper lip length = -0.30 (proximal ridge count) + 26.38	0.01856	0.02	7.13	0.008
		Mouth width = -0.56 (proximal ridge count) + 58.89	0.01825	5.49	6.00	0.015
Female	Left Hand	Lower vermilion width = 0.28 (proximal ridge count) + 10.09	0.05798	1.74	6.65	0.011

ridge count and nasolabial distances in the male population of Hausa. The correlation analysis showed that in males the left proximal ridge count correlated ($p < 0.05$) negatively with nasal length, philtrum length, upper lip length and mouth width. The upper lip length and nasal width correlated ($p < 0.05$) negatively with left ulnar ridge count and right radial ridge counts, respectively.

Table-6 shows the correlation between thumbprint ridge count and nasolabial distances in the female population of Hausa. A positive correlation ($p < 0.05$) was observed between ulnar ridge count with nasal length and lower vermilion width. In females, a positive correlation was observed only between lower vermilion width and left proximal ridge count. Figures-3-5 show the scatter plot of the relationship between the thumbprint ridge counts and nasolabial distances. Statistically significant ($p < 0.05$) correlations were observed in most of the plots.

Table-7 shows stepwise multiple regression analysis for prediction of facial distances from thumbprint ridge count. Using stepwise multiple regression analysis, only proximal ridge count predicts the facial distances. The left proximal ridge counts predict most of the facial distances in males. In females, only the left proximal ridge counts showed potential in the prediction of facial distances (Table-7).

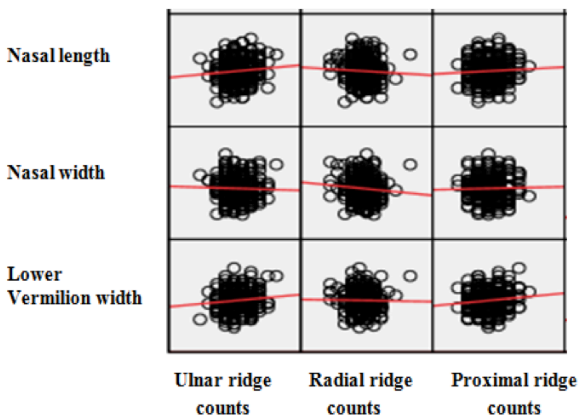

Figure 3- *Scatter plot matrix for relationship between right thumbprint ridge count and nasolabial distances (mm) in males.*

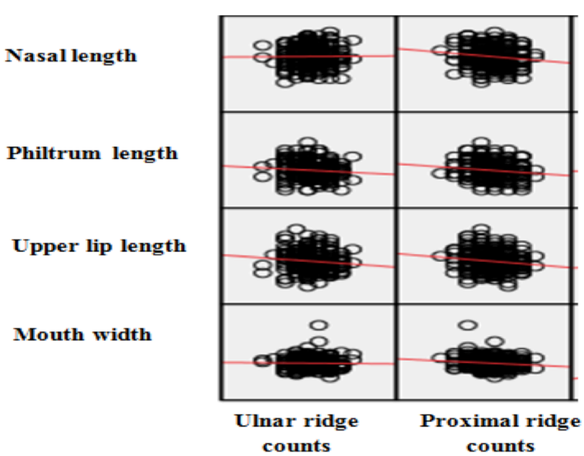

Figure 4- *Scatter plot matrix for relationship between left thumbprint ridge count and nasolabial distances (mm) in males.*

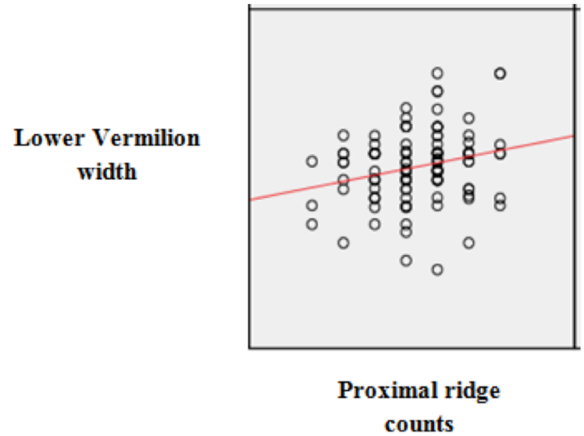

Figure 5- *Scatter plot matrix for relationship between left thumbprint ridge count and nasolabial distances (mm) in females.*

4. Discussion

The phenotypic formation of fingerprints is determined by factors such as the ratio of volar pad height to width in utero [25] and influenced by genetic interactions with the intrauterine environment [26]. Embryonic gene expression and molecular interactions also mediate the development of craniofacial phenotype [27], and as humans grow different parts of the face are also affected by hormonal and biomechanical factors [28, 29]. Facial and fingerprint phenotypic characteristics are uniquely determined by the interaction of a specific genotype and the environment [30]. This study hypothesized that there could be some level of relationship between the thumbprint ridge count and facial distances among the Hausa population of Nigeria. This was tested through determining the correlation between the thumbprint ridge count and facial distances in the nasolabial region. We also determined the potential of thumbprint ridge count in prediction of facial distances in the same region.

The correlation observed between the ulnar and proximal ridge counts in the present study may be supported by the fact that the unique identity exhibited by the individual facial expression is also exhibited by fingerprints [30]. Therefore, it was suggested that the two traits (fingerprint and facial features) may share the same intrinsic factor that controls them, leading to some significant degree of correlation between the two variables [4]. In previous studies, the features of both fingerprint patterns and facial morphology were reported to be strongly influenced by genetic factors. Some genes that were reported in low to medium levels in the skin were found to play a key role in the determination of facial features [31, 32]. Some level of association was also documented between thumbprint patterns and facial proportions [4]. These explain the possible linear correlations observed in this study.

In the present study, fingerprints showed potential in predicting nasolabial features in the Hausa population of Nigeria. Similarly, in the previous studies fingerprint features were used to generate face borders [33], face borders and ears [34], face models including eyebrows, eyes and mouth [35], inner face parts including eyes, nose and mouth, and the face parts including eyebrows, eyes and nose [36]. However, in this study the proximal part of the thumbprint was observed to be the only variable that could-predict nasolabial complex in the Hausa population. This may lead to the hypothesis that the proximal part of the thumb and the proximal (lower) part of the face may be controlled by the same genetic factor in utero.

Another possible explanation of prediction may also be supported by the fact that the different areas of the fingers seem to respond to different developmental instructions, which may lead to the consideration of the different areas as separate entities during analysis [37]. It was also reported that primary ridge formation does not occur simultaneously on the volar skin surface. The formation usually starts at a certain area in the middle of the volar pad (the ridge anlage), along nail furrow and little later along the interphalangeal flexion creases. The three ridge systems on the fingertips meet at triradii [2]. This may highlight the possible existence of different factors that control different areas of the thumb and a possible relationship with different body parameters, including the face. But this finding needs to be interpreted with caution as many possible distances within the nasolabial regions were also not considered in this study. Moreover, other thumbprint features such as ridge minutiae were not explored in this research. Therefore, further comprehensive studies are needed using other features of both face and thumbprints. There is also a need for similar studies in other populations for better explanations of the trend and pattern of this linear relationship across different populations.

To emphasize on the importance of this study, its results can be utilized by the forensic community where the need of prediction of facial variables arises using fingerprints obtained from crime scenes. This prediction may also serve as a way of establishing the identity of a suspect under investigation. By extension, the thumbprint proximal ridge density may be studied in individuals with nasolabial region abnormalities (example cleft lip and cleft palate) and their relatives in order to establish diagnostic criteria for individuals at risk of such abnormalities. However, the model generated from this study needs to be tested on more samples or subsamples of the Hausa population in order to determine the applicability and accuracy of the model reported in the present study.

5. Conclusion

Thumbprints correlate with facial distances of the nasolabial region. Among the ridge count of the three areas of the thumbprint, only the proximal ridge count exhibits potential in prediction of nasolabial facial distances among the Hausa population of Nigeria. Thus, the proximal part of the thumbprint may respond to same instruction in utero with the proximal (lower) part of the face.

Conflict of Interest

Authors declare no conflict of interest.

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