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A Study of Palatal Rugae Patterns and Maxillary Inter-Canine Distance in a Jordanian Population Sample



دراسة أنماط الغضون الحنكية والمسافات بين الأنياب العلوية عند عينة من المجتمع الأردني

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Abstract

The study of palatal rugae has an important role in establishing personal identity and facilitating population identification. The current work analyzed the pattern of palatal rugae among an adult Jordanian population and searched for any gender differences.

A total of 100 random dental casts were included in this study. Number and pattern of palatal rugae regarding length, shape, direction, and unification of rugae were identified. In addition, measurement of maxillary intercanine widths (MIW) using digital Vernier caliper was done.

Palatal rugae on the right side outnumbered those on the left side. Males had more rugae in general than females. The commonest rugae in both sexes were serpiginous. Primary and forward rugae showed the highest frequency. A diverging form of unification was more prevalent than a converging form. Apart from a total number of convergent, divergent and secondary rugae, the total number of other rugae differs significantly between males and females.

The study showed characteristics of palatal rugae in a Jordanian population which could be gender specific, facilitating their identification. It revealed the presence of sexual dimorphism, and sex can be predicted using either logistic regression equation or CART model.

Keywords: Forensic Science, Forensic Odontology, Palatal Rugae, Rugoscopy, Jordanian Population, Anterior Maxillary Arch.

المستخلص

تمتلك دراسة الغضون الحنكية دوراً هاماً في تشكيل الهوية الشخصية وتسهيل التعرف على السكان. وفي هذه الدراسة تم تحليل نمط الغضون الحنكية عند السكان الأردنيين البالغين والبحث عن أي اختلافات بين الجنسين.

أجريت الدراسة على عدد 100 قالب أسنان أخذت بشكل عشوائي، وتم تحديد عدد ونمط الغضون الحنكية فيما يتعلق بطول وشكل واتجاه وتفرع الغضون. وبالإضافة إلى ذلك تم قياس عرض الفواصل بين الأنياب العلوية (MIW) باستخدام الفرجار الورني الرقمي.

تفوق عدد الغضون الحنكية في الجانب الأيمن عن تلك الموجودة في الجانب الأيسر. وكذلك فاق عدد الغضون الحنكية عند الذكور مقارنة بالإناث بشكل عام. وكانت الغضون الحنكية المتموجة أكثر الأنواع شيوعاً في كلا الجنسين. كما مثلت الغضون الحنكية الابتدائية الكبيرة الحجم وأيضاً المتجهة نحو الأمام أعلى معدل حدوث. وكان شكل التباعد المتباين أكثر انتشاراً من النموذج المتقارب، كما أن أنواع الغضون الحنكية اختلف بشكل كبير بين الذكور والإناث.

وضحت الدراسة خصائص الغضون الحنكية في السكان الأردنيين والتي يمكن أن تكون محددة، وتسهل التعرف عليهم، كما كشفت عن وجود اختلاف بين الجنسين فيما يتعلق بذلك، ويمكن من خلاله التنبؤ وتحديد الجنس باستخدام معادلة الانحدار اللوجستي أو نموذج CART.

الكلمات المفتاحية: علوم الأدلة الجنائية، طب الأسنان الشرعي، الغضون الحنكية، تَطْيِيرُ الغُضُون، المجتمع الأردني، قَوْسُ الفَكِّ العُلْوِيِّ الأمامي



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1. Introduction

Human identification is one of the main objectives of forensic sciences. Nowadays, palatal rugae patterns serve as an alternative method for identification purposes when finger or lip prints cannot be recognized due to burn or decomposition as a necro identification technique [1]. Investigations revealed that palatal rugae are well-preserved even after third-degree panfacial burns, being shielded by the lips, the buccal pad of fat, cheeks, tongue, teeth, and bone and can resist postmortem decomposition changes for up to one week [2]. Moreover, Coslet et al. [3] recorded that the clinical removal of palatal rugae is not a permanent event, as the rugae returned back within several months. They have also been used when post-mortem dental identification has not been possible, as in edentulous mouths [4]. Therefore, they are of the utmost importance, especially in mass and aviation disasters when antemortem data were already present as dental casts or intraoral photographs. However, palatoscopy might have no role in crime scene investigations [1].

Palatal rugae are protrusions arising from incisive papilla then extending laterally [5]. They are formed of dense connective tissue (fibroblasts and collagen fibers) below epithelial cells. Hydrophilic glycosaminoglycan is a main component of rugae. It promotes tissue swelling and thus maintains the palatal pattern [6].

Physiologically, they facilitate food crushing, swallowing and prevent food loss from the mouth. Due to the presence of gustatory and tactile receptors, they aid in the perception of food taste and texture [7]. In children, they play an important role in suckling and speech [8].

Palatal rugae are highly individualistic with respect to the combined patterns, number, shape, unification, length, width, prominence and orientation [9] and could be used as a personal print [10]. The first scientist that used palatal rugae in identification was Allen in 1889 [11]. They are used in human identification not only due to their singularity and uniqueness but also due to low utilization cost, simplicity, reliability, and stability as they only change in length during a person's growth [12-13].

Palatal rugae are present in most mammalian species, while their number and pattern are species specific [7]. The

patterns of palatine rugae exhibit both racial and gender variations [14]. The present study aimed to analyze the palatal rugae patterns and anterior maxillary arch among an adult Jordanian population and to examine for any differences that could be related to gender.

2. Materials and Methods

The study sample consisted of 100 random dental casts which included 50 males and 50 females in the age group of 19-58 years from the Royal Medical Services Hospital, Jordan during 2018.

Informed consent was obtained from all participants included in the study, explaining the aim and the procedure of the study. Complete confidentiality was ensured through the entire study procedure. The study protocol was approved by the Royal Medical Services Human Research Ethics Committee.

Alginate impressions of maxillary arches were made using suitable perforated metal trays. Subjects were seated upright on the dental chair and the dentist stood behind the subjects for firm control of the impression tray. For the cast generation, immediate pouring of gypsum into the impressions was done to avoid any dimensional changes, together with the use of a standard vibrator to remove any air bubbles. Then the casts were sterilized and trimmed in the cast trimmer [15].

All selected casts were free of air bubbles or voids, especially at the anterior third of the palate. They belonged to Jordanian individuals who were free of any diagnosed congenital abnormalities, trauma or surgery at the anterior palatal region, or orthodontic treatment. For accurate odontometric measurement, the study also excluded subjects with any morphological or pathological alterations of teeth.

The rugae were highlighted using a sharp graphite pencil under adequate light and magnification using hand lens (RS Pro magnifying glass, 5x Magnification) to enhance the visualization of the palatal rugae on these casts and were analyzed macroscopically (calcorugoscopy).

Subsequently, the pattern of palatal rugae was identified according to its length, shape, direction and unification form, using the classification of Kapali et al. [12], and Da Silva classification [16].

Rugae length: measurements were taken directly from



the cast from the origin of each ruga (near the mid-palatine raphe) to its terminal end, using digital vernier caliper with an accuracy of 0.02 mm (Figure-1). Rugae were then categorized according to their length into:

1. Primary rugae: more than 5mm.
2. Secondary rugae: ranging from 3 to 5 mm.
3. Fragmentary rugae: less than 3 mm in length.

The shapes of rugae were classified into five types: curved, wavy, straight and circular (Figure-2):



Figure 1- Digital Vernier calipers device.



Figure 2- Different shapes of palatal rugae.

- 1) Straight (linear): They follow a linear pattern from their origin to termination.
- 2) Curved: They had a crescent shape.
- 3) Serpiginous (wavy): These are curved rugae with another slight curve at the origin or termination.
- 4) Circular: They are rugae that form a continuous circle.
- 5) Point

The direction of the rugae was determined by measuring the angle between the line joining its origin and termination and the line perpendicular to the median raphe. Rugae were classified according to direction into:

- 1) Forwardly directed rugae that were associated with positive angles.

- 2) Backwardly directed rugae that were associated with negative angles.
- 3) Perpendicular rugae having angles of zero degrees.

Unification occurs when two rugae have a common origin or termination. Therefore, unification can be:

- 1) Diverging: If two rugae had a common origin from the midline (mid-palatine raphe) but separate terminations.
- 2) Converging: Two rugae with different (separate) origins from the midline, but united at their ends laterally.

Odontometric measurements were performed using digital Vernier caliper. The maxillary inter-canine width (ICW) or maxillary anterior arch width was measured as the distance between the cusp tips of right and left maxillary canines (Figure-3).



Figure 3- Measurement of intercanine distance of maxillary arch (Canine arch width) using digital Vernier calipers.

Statistical Analysis

The data were statistically analyzed using IBM SPSS Version 22.0 and “rpart” package [17] in R [18]. The descriptive statistics were calculated (mean, range, standard deviation, median and IQR). Correlations between quantitative variables were tested using Pearson’s correlation coefficient. All reported p values are two-sided ($p > 0.05$: non-significant, $p < 0.05$: significant).

To determine the predictive performance of different palate rugae characteristics among the study sample, we used two statistical methodologies: the conventional method and the classification and regression trees-guided (CART-guided) methods.

We divided the dataset into two sets: training set and validating set. The training set included 76 cases (50% of them were males) and was used to determine the predictors of a male using the conventional method or the CART-model. The validation set ($n=24$, 50% of them were males) was used to test the models which were built in the training set to verify that the accuracy of prediction was sufficient.

Conventional Method

In the conventional statistical method, we conducted bivariate analysis first to determine the potential predictors, then, multivariate analysis to determine the independent predictors among the potential predictors. In bivariate analysis, we used univariate logistic regression. Odds ratio (and 95%CI) and Wald statistic were calculated. Odds ratio (OR) and 95%CI were used for measuring the association between sex and different predictors. If OR is > 1 , the number of rugae is more among males; and if OR is < 1 , the number of rugae is more among females. An OR of 1 indicates no association. The potential predictors were ordered according to their strength of association with sex using Wald statistic.

Multivariate analysis was conducted using multiple logistic regression models. According to the "one in ten rule" [19], which states that one predictive variable can be studied for every ten events, the maximum number of predictors allowed in the model is three (Number of males in the training set was 38). We chose the predictors with the highest Wald statistic on the bivariate analysis to be included in the model. The accuracy of the model was estimated in the training and validation sets by dividing the number of correctly-classified individuals by the total number of participants in each set.

CART-Guided Method

CART is a non-parametric regression approach in which the data are sequentially split into dichotomous groups, such that each resulting group contains observations which have a similar outcome [20]. We used CART to find the important predictors of male sex among the study sample, to determine the optimal cut-off values of quantitative predictors and to detect the potential interactions between the important predictors. The total number of rugae and inter-canine distance were entered into the CART model.

The end product of a typical CART analysis is a tree that starts with a "root node" which contains the observations from which the tree will be grown. The observations are then partitioned into two "child nodes" - each containing a subset of the observations- according to the value of one of the predictors.

Each child node may be further divided, again according to the value of one of the predictors. This process continues until any further splitting would not improve the overall R-squared (overall fitting of the model) by 1%. The final child nodes are named terminal nodes and they form a complete partition of the observations in the root node.

The significance of the test results was quoted as two-tailed probabilities and judged at the 5% level.

3. Results

A total of 100 random dental casts were included in this study (50 males and 50 females). The age range of females was 19–58 years with a mean of 34.20 ± 11.59 years, while the age range of males was 19-54 years with a mean of 31.90 ± 11.25 years. There was no statistically significant difference between males and females regarding the age.

The current work revealed that palatal rugae pattern in all 100 subjects was distinct and unique. None of the patterns were identical and also no bilateral symmetry was observed in any individual's cast.

Lateral Differences

The present study reported the absence of bilateral similarity. Meanwhile, no statistically significant difference was detected between right and left side values of all measured parameters.

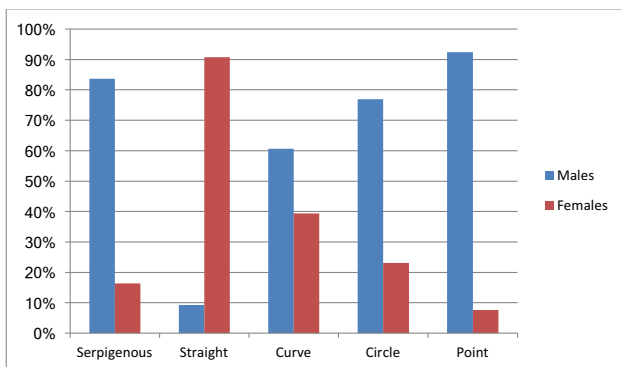
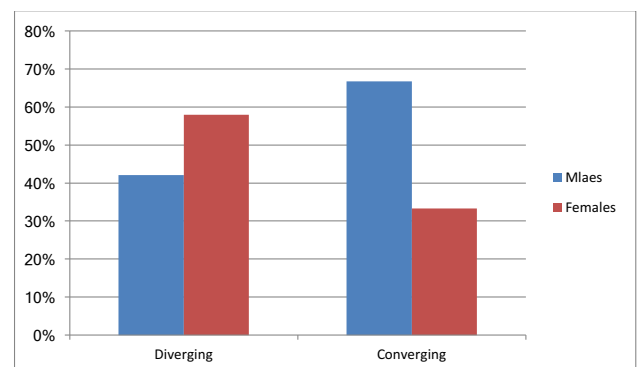
Table-1 and Figure-4, 5, 6, 7 show the descriptive statistics of different characteristics of palatal rugae, where the total number of palatal rugae on the right side was 393, which exceeded that on the left side, which was 377. Males had more rugae in general than females. The most common type of rugae in both sexes was the serpiginous type, followed by the straight then curved type. The most frequent shape of rugae in males was serpiginous rugae, while straight shape was the commonest type among females. Males had a significantly higher number of curved, circular and point types of rugae than females.

Diverging palatal rugae showed significantly higher incidence than converging rugae. Regarding the length,



Table 1- Descriptive statistics of palatal rugae patterns in both genders.

Rugae patterns	Males				Females				Total
	Right	Left	Total		Right	Left	Total		
			No.	%			No.	%	
Shape									
1. Serpiginous	116	126	243	83.7	25	22	47	16.3	289
2. Straight	12	11	23	9.3	115	110	225	90.7	248
3. Curve	37	26	63	60.6	20	21	41	39.4	104
4. Circle	5	5	10	76.9	1	2	3	23.1	13
5. Point	28	21	49	92.4	3	1	4	7.6	53
Unification									
1. Diverging	13	11	24	42.1	17	16	33	57.9	57
2. Converging	0	4	4	66.7	1	1	2	33.3	6
Length									
1. Primary	156	165	321	52.7	141	147	288	47.3	609
2. Secondary	26	18	44	45.4	30	23	53	54.6	97
3. Fragmentary	29	21	50	78.1	11	3	14	21.9	64
Direction									
1. Forward	154	160	314	60.9	100	101	201	39.1	515
2. Backward	23	14	37	33.1	43	32	75	66.9	112
3. Perpendicular	6	9	15	20	36	39	75	80	90

**Figure 4-** Distribution of the shapes of palatal rugae according to the gender**Figure 5-** Distribution of the unification of palatal rugae according to the gender.

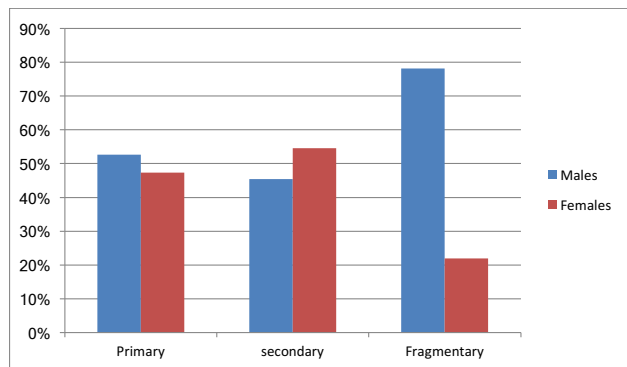


Figure 6- Distribution of the length of palatal rugae according to the gender.

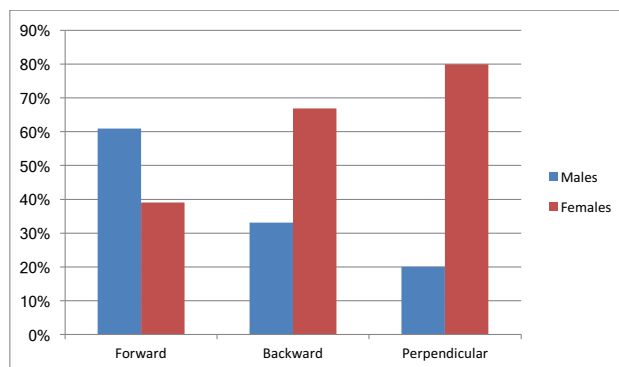


Figure 7- Distribution of the direction of palatal rugae according to the gender.

Table 2- Descriptive statistics of palatal rugae patterns with tests of significance.

Rugae patterns	Range	Median (IQR)	Test	(p-value)
Shape				
1. Serpiginous	0-8	3 (2)		
2. Straight	0-6	2 (2.75)		
3. Curve	0-3	1 (2)	Friedman=232	(<.001)
4. Circle	0-1	0 (0)		
5. Point	0-7	0 (0)		
Unification				
1. Diverging	0-3	0 (1)	Wilcoxon-signed rank=28	(<.001)
2. Converging	0-1	0 (0)		
Length				
1. Primary	1-10	6 (2)		
2. Secondary	0-6	0 (1)	Friedman=153	(<.001)
3. Fragmentary	0-7	0 (1)		
Direction				
1. Forward	0-11	5 (3)		
2. Backward	0-6	1 (2)	Friedman=86	(<.001)
3. Perpendicular	0-5	0 (2)		

Table 3- Descriptive statistics of maxillary intercanine distance among males and females with tests of significance.

Rugae patterns			Range			p-value
Range (cm)	Mean ±SD (cm)	Median (cm)	Range (cm)	Mean ±SD (cm)	Median (cm)	
3-4	3.51±0.24	3.5	2.9-3.9	3.36±0.23	3.35	0.002**

**Mann-Whitney test



Table 4- Bivariate analysis to detect the predictive performance of palate rugae in discriminating males from females.

Predictor	Sex	Median	Interquartile Range	(Min, Max)	Wald statistic	Odds ratio
					(p-value)	(95% CI)
Total_straight	Male	2	(1.0)	(0 , 4)	25.4	.27
	Female	4	(1.3)	(0 , 6)	(<.001)	(0.16 , 0.45)
Total_serp	Male	4	(1.0)	(1 , 8)	22.7	3.14
	Female	2	(1.3)	(0 , 5)	(<.001)	(1.96 , 5.03)
Total_Forw	Male	6	(3.0)	(0 , 11)	16.0	1.52
	Female	4	(4.0)	(0 , 9)	(<.001)	(1.24 , 1.87)
Total_Perp	Male	0	(0.0)	(0 , 5)	12.8	.45
	Female	1	(2.3)	(0 , 5)	(<.001)	(0.29 , 0.7)
Distance	Male	3.5	(0.3)	(3 , 4)	8.4	13.82
	Female	3.35	(0.3)	(2.9 , 3.9)	(.004)	(2.34 , 81.64)
Total_point	Male	0	(2.0)	(0 , 7)	7.9	3.65
	Female	0	(0.0)	(0 , 2)	(.005)	(1.48 , 8.98)
Total	Male	8	(4.0)	(5 , 15)	7.4	1.36
	Female	7	(2.0)	(4 , 10)	(.006)	(1.09 , 1.7)
Total_Back	Male	0	(1.0)	(0 , 3)	7.2	.63
	Female	1	(3.0)	(0 , 6)	(.007)	(0.45 , 0.88)
Total_frag	Male	0	(2.0)	(0 , 7)	6.3	1.80
	Female	0	(0.0)	(0 , 3)	(.012)	(1.14 , 2.84)
Total_curve	Male	1	(1.3)	(0 , 3)	4.2	1.65
	Female	1	(1.0)	(0 , 3)	(.039)	(1.03 , 2.67)
Total_pry	Male	6	(2.0)	(3 , 10)	3.9	1.30
	Female	6	(3.0)	(1 , 9)	(.048)	(1 , 1.68)
Total_circle	Male	0	(0.0)	(0 , 1)	3.9	3.92
	Female	0	(0.0)	(0 , 1)	(.049)	(1.01 , 15.22)
Total_Diverg	Male	0	(1.0)	(0 , 3)	1.2	.75
	Female	0	(1.0)	(0 , 3)	(.266)	(0.46 , 1.24)
Total_converg	Male	0	(0.0)	(0 , 1)	0.7	2.09
	Female	0	(0.0)	(0 , 1)	(.409)	(0.36 , 11.95)
Total_2ry	Male	0	(1.0)	(0 , 5)	0.4	.91
	Female	0	(2.0)	(0 , 6)	(.529)	(0.69 , 1.21)



primary rugae were the predominant rugae while the most frequent direction of palatal rugae was the forward one.

On comparing different characters of palatal rugae, there were statistically significant differences in the frequencies of different palatal rugae parameters or characteristics as shown in Table-2.

Regarding the rugae shape, all the pairwise comparisons show statistically significant differences, except for the following two pairs: Serpiginous vs Straight and Circle vs Point. Furthermore, regarding the length and direction of rugae, all the pairwise comparisons show statistically significant differences, except between secondary and fragmentary and that between perpendicular and backward; i.e. forward rugae showed a significant difference when compared with backward or perpendicular directions. (Table-2)

Table-3 shows that maxillary intercanine distance was significantly larger among males.

Predictive performance of palate rugae in discriminating males from females

A- Conventional Analysis

Bivariate analysis

Table-4 and Figure-8 show the association between

characteristics of rugae pattern and the gender. They were arranged according to the strength of association. Apart from a total number of convergent, divergent and secondary rugae, the total number of other rugae differs significantly between males and females. The intercanine distance was significantly larger among males. Males have more rugae in general. All the types of rugae were more frequent among males, except linear, diverging, perpendicular, backward and secondary rugae, which were more common among females.

Multivariate Analysis

A logistic regression model was built using data of the training set. Due to the limitation of the sample size, only three predictors could be included in the model. We selected the predictors with the highest Wald statistic on the bivariate analysis (table 4); namely the total number of straight, serpiginous and forward rugae. Logistic regression results in the following equation to estimate (p), which is the probability of being male.

$$p = 1/(1+e^{-(-3.2775-3.664*X_1+1.6716*X_2+1.5159*X_3)})$$

Where:

$e \approx 2.7183$ (which is Euler’s Number)

X_1 is the total number of linear rugae

X_2 is the total number of forward rugae

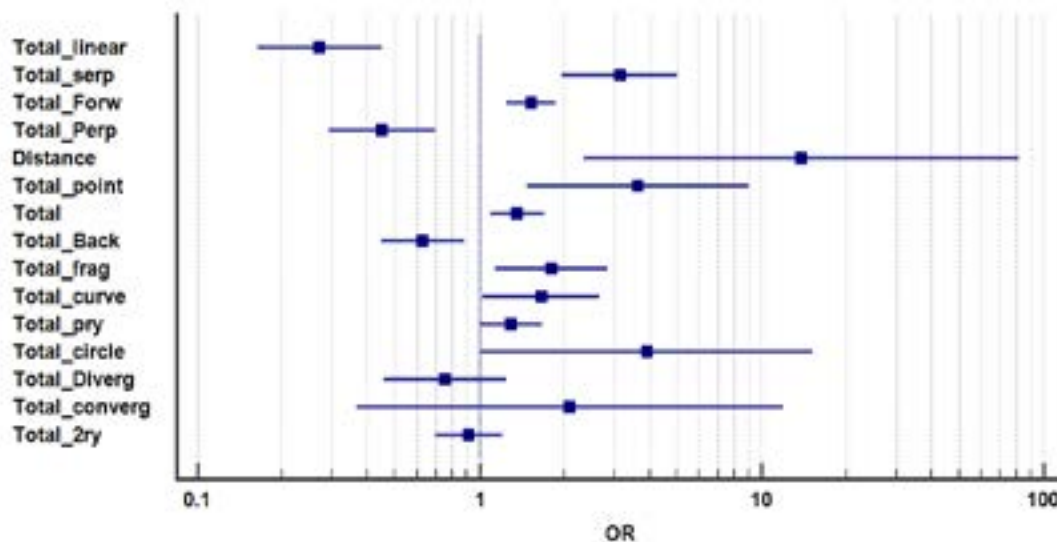


Figure 8- Bivariate analysis to detect the predictive performance of palate rugae in discriminating males from females.



X_3 is the total number of serpigenous rugae

If the estimated probability is > 0.5 , the participant is predicted to be a male. Otherwise, they are predicted to be a female. Using this equation, the number of correctly-classified participants was 71 in the training set (Training accuracy = 93.42%; 95% CI: 85.31% to 97.83%) and 22 participants in the validation set (Validation accuracy=91.67; 95% CI: 73% to 98.97%).

B- Classification and Regression Trees (CART)-Guide Methodology (Figure-9)

All the predictors were included in the CART model.

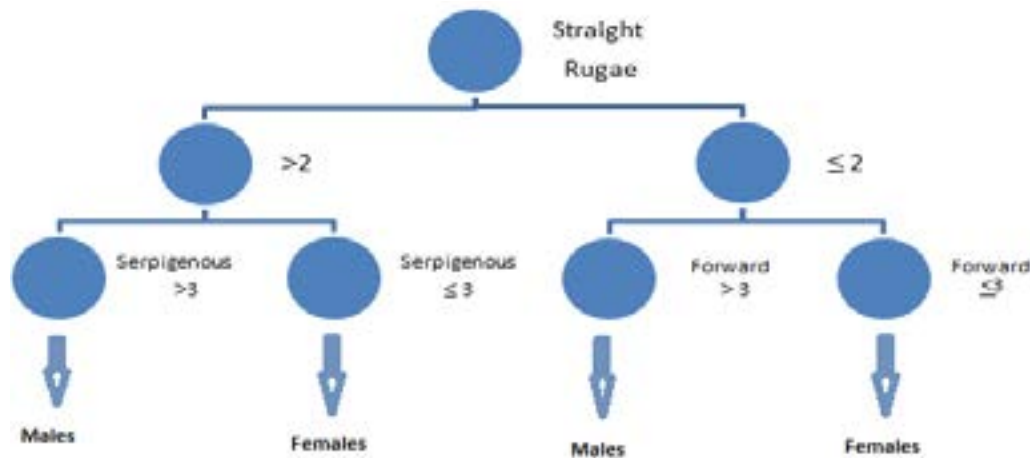


Figure 9- Classification and Regression Trees (CART)-Guide Methodology.

CART classified the training set according to the total number of straight rugae into two nodes: node 2 on the left and node 3 on the right. Node 2 ($n=33$) included all the cases among whom the total number of straight rugae was more than 2. This was further subdivided into two nodes, node 4 and node 5, according to the total number of serpigenous rugae. Node 3, which included all cases with two or less straight rugae, was further subdivided, according to the total number of forward rugae into two nodes, node 6 and node 7. According to the CART-tree, members of nodes 4 and 6 are predicted to be males, and members of nodes 5 and 7 are predicted to be females

Node 4 ($n=7$) included cases with more than 3 serpigenous rugae and more than 2 linear rugae. Five of them (71%) were males.

Node 6 ($n=31$) included cases with more than 3 forward rugae and two or less linear rugae. Thirty of them (97%)

were males.

Node 5 ($n=26$) included cases with 3 or less serpigenous rugae and more than 2 linear rugae. All of them were females.

Node 7 ($n=12$) included cases with 3 or less forward rugae and two or less linear rugae. Nine of them (75%) were females. Thus, training accuracy was 92% (95% CI: 83.47 to 96.98%), as the CART predicted the correct sex among 70 participants.

Among the validation set, 11 participants were allocated to node 5 (10 of them were females) and 3 to node 7 (2 of them were females), 10 to node 6 (all of them were males) and none to node 4. Thus, validation accuracy was

97% (95% CI: 80.67% to 99.98%).

4. Discussion

Identification using fingerprints are limited by post-mortem changes associated with temperature, time and humidity [21]. Identification via dental records also may be inconclusive, because of dental treatment or loss after the creation of a dental record. DNA profiling is accurate but expensive and time-consuming if used in a large population study. Since the rugae pattern is well-established to be highly individualized and stable throughout life, they can therefore, be used reliably as a reference landmark during forensic identification [22].

Rugae patterns may be specific to racial groups, facilitating population identification, especially post disasters. A significant association between rugae forms and ethnicity has been observed by various authors [12, 23-25]. Kashima

[26] reported that the palatal raphae of Japanese children are broader than those of Indian children. These population differences may result from environmental effects or be genetically controlled. Unidentified genes may affect the orientation of the collagen fibers during embryogenesis and control rugae patterns in various populations [27].

Kapli et al. [12] and Jain et al. [9] reported that rugae growth during palatal development throughout childhood and adolescence only resulted in a change in their length, which becomes constant after adolescence. Therefore, data obtained before adolescence may contain growth-related errors.

The palatal rugae patterns in the present study were individualized and unique for each subject. This agrees with previous studies in Jordan [28], India [13], and Indonesia [29] where none of the patterns were identical or alike. Furthermore, no bilateral symmetry was observed in any individual. Mustafa et al. [28] in Jordan observed that the qualitative analysis yielded an absolute 100% individuality of palatal rugae patterns. The number and pattern of palatal rugae in mammals are species-specific, and asymmetry of palatal rugae is an exclusive feature of human beings [30, 31]. That is why no two palates are identical regarding their rugae pattern, even in dizygous twins [13].

The current study recorded that a total number of rugae in Jordanian males outnumbered those in females and this may be attributed to the difference in jaw size confirmed by significantly wider intercanine arches in males. The same finding was observed by Simmons et al. [30], Poojya et al. [4], Indira et al. [13] and Syed et al. [32]. However, this contradicts the finding reported by Suhartono et al. [29] where palatal rugae in Indonesian females were slightly higher than males.

The total number of palatal rugae on the right side (393) exceeded that on the left side (377). This finding agrees with many previous studies done on different populations. [12, 13, 29, 32]. Syed et al. [32] explained that due to the greater use of right side teeth for mastication than the left side in the Saudi population, more people there developed palatal rugae characteristics on the right side. On the contrary, more rugae were observed on the left side in both genders in the study of Simmons et al. [30] and Ibeachu et al. [33].

The commonest type of rugae in both sexes was the ser-

piginous type, followed by the straight then curved type. This coincides with Kotrashetti et al. [34].

Azab et al. [35] reported that the wavy shape was the predominant rugae among Egyptians. Similarly, Abdellatif et al. [36] observed that wavy rugae were the most prevalent forms in Saudi children, while curved shape was significantly greater in Egyptian children. This is consistent with the results of Australian Aborigines and Caucasians where wavy (40.6%) and curved (25.8%) rugae were the most prevalent in Caucasians while straight, circular and unifications were less common in Caucasians [37]. Abdulmajid et al. [38] recorded that wavy and curved rugae were the commonest types among Libyan school children, followed by cross-linked (14.96%) and then by diverging unification (14.96%) and straight (14.28) PR, while circular and converging rugae were not found. This difference may be due to exclusion of fragmentary rugae, the difference in sample size, or sample age groups, as their studies were done on children.

Regarding rugae unification, diverging palatal rugae showed significantly higher incidence than converging rugae. Similarly, Abdellatif et al. [36] observed that diverging rugae were more frequent in Saudi children. Contrary to these findings are those found by previous studies on the Egyptian population where converging rugae were predominant [35, 36].

The current study showed a significant difference between males and females in the total number of rugae and in the frequency of different rugae parameters regarding shapes, length, and direction of rugae. However, there was no statistically significant difference between males and females regarding the unification. The converging pattern was predominant in males and the diverging pattern was found to be dominant in females, similar to the study of Shetty et al. [39].

The most frequent shape of rugae in males was serpiginous rugae, while straight shape was the commonest type among females. Nearly similar results were reported in a Tibetan population [24] where men had more curved rugae than women, while straight rugae were more common in women.

Circular and point shapes together with unifications were few in number in the present work, while cross-link rugae were not observed at all. Similar observations were



reported by Abdellatif et al. [36] and Fahmi et al. [40] in studies on the Saudi Population. The circular shape was the least recorded. Males had a significantly higher number of curved, circular and point types of rugae than females. This coincides with an Indian study [8] where the circular type of rugae was statistically greater in number in males. In addition, Fahmi et al. [40] observed that Saudi males had a significantly greater number of circular type. These studies show the great similarity between both Jordanian and Saudi populations.

On the other hand, Nayak et al. [41] reported no incidence of circular pattern in an Indian population, while unification was rare. Furthermore, no significant difference in characteristics in men and women was detected in their study. It was noted that the Africans had statistically greater numbers of unification and circular rugae than other races [42].

Regarding the length, primary rugae was the predominant rugae and males had a significantly higher number of primary rugae than females; this was in concordance with study of Ibeachu et al. [33]. Conversely, Saraf et al. [8] did not find any significant difference in rugae length between both sexes, and this may be due to exclusion of secondary and fragmentary rugae from their study. Kapali et al. [12] did not reveal any significant differences in the number of primary rugae between Australian Aboriginal males and females.

Secondary rugae were more common in females; the same finding was reported by Muhasilovic et al. [43], while Dohke and Osato [44] showed the opposite on studying the Japanese population, where there were fewer numbers of secondary rugae in the females than the males. This coherent species difference could reflect the importance of studying the palatal rugae in different populations and making correlation studies among them.

The intercanine distance was particularly chosen for this study, as canine teeth are usually the last teeth to be lost due to their greater resistance to periodontal diseases, plaque, calculus or severe trauma like air disasters, hurricanes or conflagration. This could be attributed to their long roots and the labio-lingual thickness of the crown and root. Also, they have a self-cleansing nature. That is why canines were considered as the 'key teeth' for personal identification [45].

Using dental cast instead of direct intraoral measurement was preferred in the current study to avoid transmission of infection between the included subjects. Measurements with digital dental calipers showed a high degree of accuracy and reproducibility. Moreover, dental casts facilitate the accurate analysis of arch symmetry and teeth alignment, rotations or absence [46].

The mean value of maxillary intercanine distance was significantly greater in males than females. A similar observation was recorded by Baheti et al. (2014) [47] and other studies in the field of forensic odontology [48-50] where canine teeth and their arch width (distance between the canine tips) have been reported to show sexual dimorphism. Variation in the intercanine distance of maxillary canine between the different populations may be attributed to genetic and environmental factors, different eating habits, race, heredity, and secular changes. [51]

Various theories explained sexual dimorphism in teeth, where males showed greater mean dimensions of teeth than females hence greater intercanine distance. The first theory stated that there is a greater thickness of enamel in males due to a long period of amelogenesis with a slower rate of maturation of teeth than in females, while the second theory stated that Y chromosomes cause a slower maturation of enamel in males [52].

Using a conventional method to test the predictive performance of palate rugae in discriminating Jordanian males from females revealed validation accuracy of 91.67% while using the CART methodology. Saraf et al. [8] stated that the use of logistic regression analysis (LRA) enabled highly accurate sex prediction (>99%) depending on the analysis of rugae shapes as the shape is more reliable and stable, while length can be affected by age, growth or regressive evolution.

5. Conclusion

The present study revealed characteristics of palatal rugae in a Jordanian population which could be specific, facilitating their identification. Furthermore, the current work stated the presence of actual sexual dimorphism regarding certain palatal rugae characteristics and maxillary intercanine distance. Together with other methods of identification, rugoscopy can be used as a valid method of differentiation between males and females using the equation



developed from logistic regression analysis or the CART model.

The current work suggests doing further palatal rugae studies on a larger sample size, on family members and monozygotic twins to ensure their individuality and hereditary aspect. The study also recommends a 3D laser scanning or digital photographing of rugae and software image analysis to facilitate data storage and sharing.

Conflict of Interest

None

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Nil

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