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Original article

Morphological analysis of Libyans palatal rugae

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Abstract
Human identification has always been a major challenge for forensic experts, especially when dealing with decomposed and severely mutilated corpses. Palatal rugae (PR) are usually preserved in such conditions and thus can be used as a supplementary, rapid, simple, or alternative technique when other methods cannot be applied. This prospective cross-sectional study aimed to analyze Palatal rugae morphology among a group of Libyans, comparing the patterns between males and females and considering the requirements for possible forensic application. Equally distributed, 200 randomly chosen Libyans of both genders were included in the study from different Libyan cities, with an age group of 18-70 years. Additional silicone impressions of the maxilla and stone casts were prepared. The PR. shape parameter was analyzed according to Thomas and Kotze 1983 PR. classification. In general, the curved shape is the most common (30.97%), followed by a straight shape, with the least convergent shape. Males had more curved rugae while females showed more straight rugae. Significantly, the circular PR. was higher in female Rt. side than male Rt. side (P=0.031). PR. Shape analysis is one of the parameters that provides potentially useful supplementary information to establish individual identity, and it is considered an alternative forensic method for individual identification in the absence of other traditional forensic methods .
Keywords. Palatal Rugae, Palatal Rugae Morphology, Forensic Method.

Introduction

Every day, forensic science faces these issues by using different methods to achieve personal identity, like visual identification, fingerprint assessment, and DNA comparison, which are the most used techniques for fast and reliable identification [1,2]. Forensic odontology is a branch of forensic medicine that is concerned with the practice of the law and the administration of justice. It comprises the correct collection, management, interpretation, evaluation, and presentation of dental evidence for criminal or civil legal proceedings or research purposes [3,4]. In forensic odontology, more techniques are helpful for the same purposes, including analysis of dental arch, cheiloscopy, antemortem periapical radiographs, pulp, and gingival morphology, missing teeth, restorative material, and palatal rugae analysis. And all of these methods can be considered to be sources of comparative material because the mouth allows a myriad of possibilities [5].

The palatal rugae analysis technique is very useful in personal identification, so the palatal rugae or rugae palatine or plicae palatine ridges [6] are "symmetrical irregular elevations of the mucosa located in the anterior part of the hard palate, made from the lateral membrane of the incisive papilla and arranged in a transverse direction from palatine raphe in the mid - sagittal plane" [7,8]. These structures have a unique protective location inside the mouth, and it is a well-established fact that the palatal rugae form a pattern that is considered unique to the individual, like fingerprints. It has been noted that even between twins, they are similar but not identical, and like the fingerprint, they have a repairable property after environmental trauma and surgical intervention, and retain their shape throughout life and stay resistant even seven days after death [9,10].

Because of the protective location of the palatal rugae, as shown in (Figure 1) inside the oral cavity, their unique structure, and their postmortem stability, they can play a big role as a forensic identification parameter and to recognize the population's ethnicity as well. Early in 1957, Sassouni V mentioned that there are no two similar palates, and as he described, the palatoprint does not change throughout the person's growth unless the length of the palatal rugae is limited under certain conditions [9].

Due to the lack of a complete standardization and interpretation for the Libyan people's palatal rugae print, this study analyzes the palatal rugae morphology of a group of Libyan people and compares the differences between Libyan males and females. The samples were collected from wide and scattered areas of Libya (East, West, and South) to include different geographic parts of Libya. The data were tabulated and organized using an Excel program for statistical analysis by the SPSS program. Objectively, each palatal shape has been classified according to Thomas Ketoz's 1983 classification.

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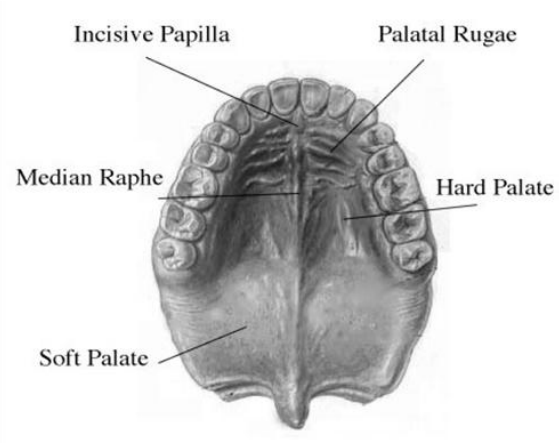

Figure 1. Palatal Rugae

Methods

This is an observational cross-sectional study that concentrates on an analysis of the palatal rugae pattern of a group of Libyan population throughout the scattered areas of Libya and compares the results between the Libyan males and females.

Randomly, the upper jaw impressions and corresponding casts/models were collected from patients of many dental clinics and dental centers in about (23) twenty-three different Libyan cities and towns. The three geographic parts of Libya (East, West, and South) were included in this study to ensure a wide distribution of data as much as possible. The two hundred (200) samples were equally divided (100 males, 100 females) and selected from about 310 samples that were taken, while 110 samples were excluded. In order of ethics that were given by the ethical committee of the faculty of dentistry of Benghazi University under No. 030, on 11/2/2021, the written/oral agreement of the person was taken before the impression took place, and the patient was informed about the study and his /her participation in it, so all the samples are publicly free for educational purposes.

A total of 200 Libyan individuals were randomly selected to participate in the study, comprising 100 males and 100 females in equal proportion. For each participant, optimum casts/models were prepared while maintaining coded identifiers and recording essential demographic information such as age, gender, and geographic area. Participants were eligible if they were Libyan, aged between 18 and 70 years, and of either gender. Exclusion criteria included the presence of infected palatal diseases, congenital malformations or defects of the palate, cleft palate, traumatized palate, orthodontic appliances, previous orthognathic surgery, severe malocclusion, syndromic conditions, or improper impressions and study models.

An irreversible hydrocolloid was used as an impression material on an appropriate perforated metal tray for the upper dental arch for all subjects. All instructions by the manufacturers were followed, such as water/powder ratios, vacuum mixing, and the use of a vibrator. The impressions were then poured with dental stone. All casts were free of air bubbles or voids, especially at the anterior third of the palate. The procedure was carried out under adequate infection control methods. Shown in (Figure 2)

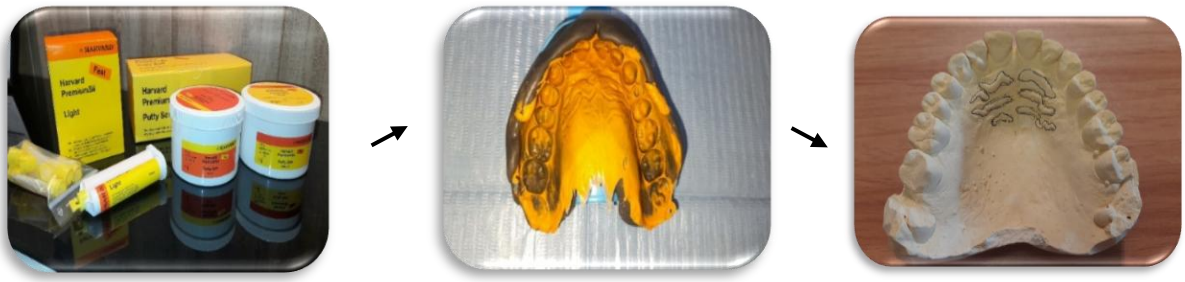

Figure 2. Casts free of voids at the anterior palate under infection control.

Palatal rugae shape identification was based on the classification of Thomas and Kotze (1983). This classification includes: number, length, shape, and unification of rugae. Each palatal rugae shape was classified into: straight, curved, wavy, dot, circular, cross -linked, papillary, breaks, branched, Converge, and Diverge shapes. The shape of each palatal rugae has been observed and recorded for each side of the palate and as a total for the individual cast. The underlying (Table 1) & (Figure 3) showed different palatal rugae's shapes**.**

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Table 1. Thomas & Kotze classification of palatal rugae' shapes.

Palatal rugea shapes								
straight	curved	wavy	dot	circular	Cross-link	papillary	breaks	branched
								

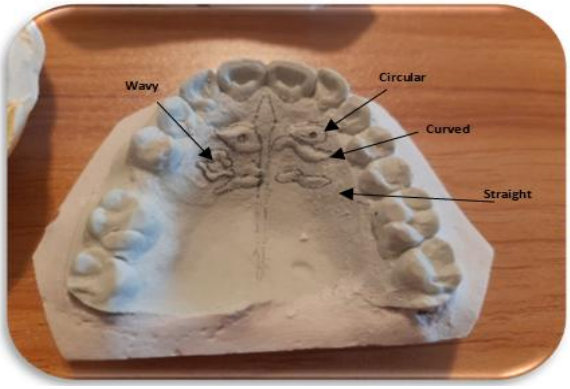

Figure 3. Distribution of palatal rugae shapes

Statistical analysis

The collected data that obtained were recorded, sorted, tabulated using the Microsoft Excel program, and subjected to statistical analysis using the Statistical Package of Social Science version 28 software package. There was no missing data in the data set. For data processing, Descriptive statistics were used to calculate means and standard deviations, to identify properties of the scale. Statistical methods were used, including frequency and Percentage for sorting the data figures (Bar chart), and the chi-squared test was used to detect any statistically significant differences in categorical variables, and the Mann-Whitney test was used to detect any statistically significant differences in continuous variables.

Results

The total percentage of each palatal rugae shape in the whole sample

(Table 2) shows the different shapes of palatal rugae in whole Libyan sample, and with respect of all 1359 palatal rugae shapes, the most common shape was curved shape 421 (30.97%) followed by Straight 418 (30.75%), wavy 361 (26.56%), circular 76 (5.59%), diverge 39 (2.86%), cross -linked 24 (1.76%), branched 18 (1.32%) and converge 2 (0.14%).

Table 2. Total percentage of PR. shapes in the population

PR. Shape	Number	Percentage%
Curved	421	30.97%
Straight	418	30.57%
Wavy	361	26.56%
Circular	76	5.59%
Diverge	39	2.86%
Cross -linked	24	1.76%
Branched	18	1.32%
Converge	2	0.14%
TOTAL	1359	100%

Palatal rugae shape comparison between males and females

In Table 3, when comparing the total of palatal rugae shapes in males and females, we observed that females had more Straight 213(50.9%), curve 222 (52.7%), circular 45 (59.2%), diverge 25(64.1%), and converge 2(100%) PR. shapes than males, on the other hand, males had more wavy 184(51%), branched 13(72.3%), and cross -linked 13 (54.2%) PR shapes than females. All these differences were not statistically significant ($p > 0.05$).

Females had more diverged rugae than males, 25(64.1%), 14(35.9%), respectively, which at the same time shows us that there was no incidence of converged palatal rugae in males (0%), while in females was 2 (100%).

Table 3. Shapes of palatal rugae in the 200 Libyan population

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PR. SHAPE	Female					Male					Mann Whitney U	P - value
	Left Side	Right Side	Total	Mean	SD	Left side	Right side	Total	Mean	SD		
Straight	97	116	213	2.13	1.5080	97	108	205	2.05	1.2820	4907	0.816
Curved	117	105	222	2.22	1.4112	94	105	199	1.99	1.2910	4534	0.239
Wavy	94	83	177	1.77	1.3390	92	92	184	1.84	1.4050	4875	0.754
Circular	20	25	45	0.45	0.6871	18	13	31	0.31	0.6150	4459	0.095
Cross-link	5	6	11	0.11	0.3451	6	7	13	0.13	0.3670	4901	0.656
Branched	3	2	5	0.05	0.2611	9	4	13	0.13	0.4180	4653	0.063
Diverge	10	15	25	0.25	0.6256	8	6	14	0.14	0.4030	4687	0.217
Converge	1	1	2	0.02	0.1400	0	0	0	0.00	0.0000	4900	0.156
TOTAL	347	353	700	7.00	1.6990	324	335	659	6.59	1.6640	4997	0.994

In Unilateral (right-sided) comparison of palatal rugae shapes between the two genders

In Table 5, males had wavier 92(52.5%), cross linked 7(53.8%) and branched 4(66.6%) shapes than females, and conversely females had straighter 166(51.8%), circular 25(73%), diverge 15(71.5%) and converge (100%) shapes than males. In addition, there was an equal incidence (105:105) of a curved palatal rugae type on the right side of both genders, with the absence of convergent shape in males' right side. The only statistically significant difference observed was in circular shape (p =0.031), where higher female right side count than males.

Table 4. Right-sided comparison of PR. shapes in males & females

PR.Shapes in males	Male Right			Female Right			Mann-Whitney U	P - value
	Total	Mean	SD	Total	Mean	SD		
Straight	108	1.08	0.992	116	1.16	1.022	4814	0.634
Curved	105	1.05	0.903	105	1.05	0.925	4992	0.984
Wavy	92	0.92	0.787	83	0.83	0.805	4673.5	0.392
Circular	13	0.13	0.338	25	0.25	0.435	4400	0.031*
Cross Linked	7	0.07	0.256	6	0.06	0239	4950	0.775
Branched	4	0.04	0.243	2	0.02	0.141	4949	0.645
Diverge	6	0.06	0.239	15	0.15	0.386	4597	0.058
Converge	0	0	0	1	0.01	0.1	495	0.317
Total	335	3.35	1.028	353	3.53	1.067	4567	0.266

** statistically significant difference (P<=0.05)*

Discussion

It had been reported that the palatal rugae pattern is specific to racial groups, and each race may have its own palatal rugae pattern characteristics [11]. And according to Thomas and Kotze's morphological classification of palatal rugae, they could be straight, curved, wavy, circular, dot, branched, papillary, breaks, converged, and diverged PR [12]. In a current study and in the whole Libyan population sample (males & females), the most common palatal rugae shape is the curve shape, followed by straight, wavy, circular, diverge, cross - linked, branched, and the least converged shapes. There is no evidence of dot, papillary, and broken palatal rugae shapes in the complete Libyan sample. The finding that curved palatal rugae is the highest ratio of palatal rugae shape, congruent with Shetty et al. [13], Nayak A. study [14], Indria AP. study [15], and Saadeh et al Lebanese study [16], which mentioned that curve PR. was the commonest shape in Mysorean, Indian, and Mediterranean populations. Other studies agreed that the commonest shape was a curved shape followed by a straight shape, conducted by Muhasilovic S. et al in Bosnia& Herzegovina, and conducted by Abdellatif A. et al., which reported the maximum curved palatal rugae followed by straight palatal rugae in both Saudi & Egyptian children [17,18].

Additionally, in the whole population sample in the present study, the second common palatal rugae shape is the straight shape, and this is in agreement with studies conducted by Abdellatif et al on Egyptions & Saudis, by Goyal M. on Rwandans, by Azab S. et al on Egyptians, Muhasilovic et al on Serbians, and by Hassan et al on Pakistanis [17-21]. Other studies in disagreement were that the (wavy/curved) shapes were the second most common shape, like in studies conducted by Kapali et al. on Australians, by Eboh S on Nigerians, by Filipovic et al on Serbians, by Ahmed A & Hamid A, and by Saadeh. M et al on Lebanese, by Shrestha et al on Nepalese, and by Shreesh Mhatre et al on Maharashtrians [22–25, 16, 26, 27].

Moreover, the third common palatal rugae shape is the wavy palatal rugae, and this also been reported in a study conducted on the Portuguese population by Santos S. & Caldas I. (Santos & Caldas, 2012). In contrast, other studies conducted by Hassan et al [21] on Pakistanis mentioned that diverge shape of palatal rugae is the third most common shape. In addition, the Indonesian study conducted by Suhartono. et al disagreed with our results regarding the curved PR. Was the third common palatal rugae shape in Indonesians [29].

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In the present study, the least common shape of palatal rugae is the convergent one; this result is consistent with the results of studies conducted by Abdulmajid Z. & Bugaighis.I on Libyans and by Sheikhi et al on Iranians [11,30]. While other studies are incongruent with our results, like those conducted by Ahmed & Hamid on Sudanese, where the cross -linked shape was the least, and on Libyans by Mahesh et al., where the circular shape was the least [25,31]. In contrast, the greatest shape was the wavy palatal rugae, which had been reported in studies conducted by Dohke M. & Osato S., on the Japanese population, by Goyal S. on the Rwandan population, by Abdulmajid Z. & Bugaighis I. on Libyan Benghzian children, by Azab S. et al., on Egyptians population, by Mahesh S.et al on Libyans in Sirte city, and by Shrestha A. et al on the Nepalese population [32,19,30,20,31,26]. Additionally, in the current results, in Libyan males, the greatest palatal rugae shape was the straight shape. This result agreed with those reported by Jurado J. et al on Colombians, by Eboh D. on Nigerians, by Suhartono A. et al. on Indonesians, and by Sheikhi M. et al on Iranians [33,29,34,11]. In other studies, Kapali S. et al [22] disagreed with this point, and it had reported that the straight rugae shape was found to be less common in Australians [22]. Also, the Indian study conducted by Dwivedi N. & Nagarajappa A. in the center of India reported that females had greater straight palatal rugae than males, and this disagreed with our results [35].

On the other side, in Libyan females, the greatest palatal rugae shape was the curved shape, which paralleled a study conducted by Buyuk S. et al were found the curved shape to be more common in Turkish females [36]. In contrast, Yad I. et al unsupported our finding where they mentioned that Libyan males had much more curved palatal rugae than Libyan females with a statistically significant difference [37]. One of the results of this present study is that there is no prevalence of dot, papillary, and broken palatal rugae forms in both genders. Additionally, there aren't convergent-shaped palatal rugae in Libyan males, which is supported by a published study presented by Abdulmajid Z. & Bugaighis I. on Libyan school children in Benghazi city, where no convergent form of palatal rugae was found in either males or females [30]. Also, there weren't any dot shapes of palatal rugae in the Portuguese population, which was reported in a study conducted by Santos S. & Caldas I [38]. In our study, males have more wavy shapes of palatal rugae than females, while females have more straight shapes of palatal rugae than males, which is consistent with the results of studies conducted by Dwivedi N. & Nagarajappa A. on Indians [35], by Mahesh S. et al.on Libyans [35,31,37,2018], and by Shrestha A. et al. on Nepalese [26]. A disagreement was reported in a Saudi Arabian study conducted by Fawzi MM. et al., which mentioned that males have more straight shapes of palatal rugae than females [39]. Another study conducted by Saadeh M.et al faced our results, and it mentioned that Lebanese females had more wavy palatal rugae forms than Lebanese males as part of the Mediterranean populations [16].

On comparing the same sides of both genders (unilateral comparison), generally, there are no statistically significant differences except that there is a statistically significant difference (P=0.031) in circular -shaped palatal rugae, where the right side of females has much more circular palatal rugae than the right side of males. This finding is generally supported by a Sudanese study conducted by Ahmed A. & Hamid A., which confirmed that females had greater numbers of circular palatal rugae on their right sides than males had on their own [25]. While the Nepalese study conducted by Shrestha A. et al. disagreed with our results in this point, where males had greater numbers of circular palatal rugae in general and on their right sides than females [26]. Finally, none of the characteristics assessed in our sample exhibited any statistically significant differences between males and females, except that the circular shape of palatal rugae was greater and statistically significant differences were observed in the right side of Libyan females than the right side of Libyan males.

Conclusion

In conclusion, this study demonstrated the palatal rugae shapes (morphology) of a group of Libyan population, where the morphology of the palatal rugae of everyone was observed and analyzed according to Thomas & Kotze's 1983 classification. Statistically significant differences between the two genders were mentioned as: the circular PR. The shape was higher on the right sides than on the left sides of their counterparts. All previous results had been compared with other local, regional, and international studies, and with resulting statistically significant differences in the present study, the palatal rugae pattern analysis, including the morphology, as an alternative method in forensic dentistry for personal identification and sex determination in the absence of traditional personal identification methods, or as a supplementary forensic method if good premortal data were preserved.

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