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Variability of palatal rugae as indicators for population diversity and sex differentiation: An observational cross-sectional study

Abstract. Objectives: to ascertain whether the palatal rugae pattern of the Basra population may be utilized to assist in determining age and sex and whether there were any connections between the Basra and other populations. **Materials and methods.** Models of maxillary impressions were taken from 250 individuals. The palatal rugae patterns on the dental casts were analyzed using a qualitative grading system based on morphology (shape). We categorized rugae based on their shape using Kapali classification. During statistical data analysis we used two main statistical methods to evaluate possible sex differences in rugae quantity and pattern Chi-squared test and unpaired t-test. **Results.** According to our results, there were 1587 rugae in total across all samples, with (776 in males) and (810 in females). Both sexes were more likely to have curved palatal rugae, but females had more curved rugae (240) than males (227). The gender distribution of rugae types does not differ statistically significantly ($p>0.05$). In both age categories, there were more curved rugae. In this study four age groups were taken, 10–20 years, 20–40 years, 40–60 years and 60–80 years. The total number of rugae among these age groups were 1587. The age group with the largest number of rugae was 20–40 with 641 rugae, followed by 40–60 with 509, 60–80 with 363 and 10–20 with 74 rugae. The distribution of rugae by age group does not change significantly ($p>0.05$). **Conclusions.** Compared to males, females have more rugae, and males typically have curved rugae however, these are statistically not significant. All age groups of females have similarly curved rugae, which makes it the most common shape in the Basra population as a whole.

Key words: palatal rugae, maxillary impressions, hard palate, dental records

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Вариабельность нёбных складок как индикатор популяционного разнообразия и половой дифференциации: наблюдательное кросс-секционное исследование

Аннотация. Цель — выяснить, можно ли использовать характер расположения нёбных складок у населения Басры в качестве вспомогательного критерия для определения возраста и пола, а также установить наличие связей между населением Басры и другими группами населения. **Материалы и методы.** Были сняты слепки верхней челюсти у 250 человек. Узоры нёбных складок на слепках зубов анализировали с использованием качественной системы оценки, основанной на морфологии (форме). Складки классифицировали по их форме, используя классификацию Капали. При статистическом анализе данных использовали два основных статистических метода для оценки возможных половых различий в количестве и узоре складок: критерий хи-квадрат и непарный t-критерий. **Результаты.** Согласно полученным данным, общее количество складок во всех образцах составило 1587 (776 у мужчин и 810 у женщин). У представителей обоих полов чаще встречались изогнутые нёбные складки, однако у женщин их количество (240) превышало аналогичный показатель у мужчин (227). Распределение типов складок по полу статистически значимо не различается ($p>0,05$). В обеих возрастных категориях было больше изогнутых складок. В данном исследовании были выделены четыре возрастные группы: 10–20, 20–40, 40–60 и 60–80 лет. Общее количество складок в этих возрастных группах составило 1587. Возрастная группа с наибольшим количеством складок — 20–40 лет (641 складка), за ней следуют группы 40–60 лет (509), 60–80 лет (363) и 10–20 лет (74 складки). Распределение складок по возрастным группам не изменяется значимо ($p>0,05$). **Заключение.** По сравнению с мужчинами у женщин больше складок, а у мужчин складки, как правило, изогнутые, однако эти различия статистически незначимы. У женщин всех возрастных групп складки имеют одинаковую форму, что делает ее наиболее распространенной в популяции Басры в целом.

Ключевые слова: нёбные складки, оттиски верхней челюсти, твердое нёбо, стоматологические карты

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INTRODUCTION

Located close to the roof of the mouth, the anterior (front) third of the hard palate is referred to as the palatal rugae region, and it is distinguished by the presence of elevated ridges known as palatal rugae. Because these ridges are specific to each person and vary in size, shape, and direction, they are of interest to disciplines like as anthropology and forensics [1]. When a person's fingerprints or dental records cannot be used to identify them because of natural catastrophes, terrorist acts, or traffic accidents, palatal rugae may be able to help [2]. In 1889, Allen made the initial suggestion to use palatal rugae patterns as personal identification [3]. It considered a valuable alternative source of information enabling the search field to be narrow because of the specific rugae characteristics, and their patterns are extremely isolated and distinctive in every individual [4].

Rugae once it formed, it remains as a stable landmark throughout life until the degeneration of oral mucosa after death, except increase in length related to normal growth [5]. According to published research, no two palates are comparable, not even those of identical twins; their palatal prints are similar but not the same [6]. Rugae patterns may be a unique character of ethnic groups facilitate the differentiation between populations [7].

Palatal rugae also called rugae palatine or plica palatinae. The word "rugae", which is derived from the Greek word "seam", refers to the stitching or joining of the segments of two biological structures during fetal differentiation [3]. According to the Glossary of Prosthodontic Terms, rugae are anatomical folds or creases of unequal fibrous connective tissue seen on the anterior palate third [8]. Three to seven asymmetrical ridges are triggered transversely by the median palatal suture and incisive papillae, and they stretch from the mesial side of the first permanent dental tooth to the front portion of the hard palate. They never make it to the midline [9, 10].

All of these alterations are believed to be caused by genes. Between the weeks 12th to 14th of intrauterine life (the third month of prenatal life), rugae traits initially emerge. Epithelial proliferation and thickening at a specific location, followed by fibroblast and collagen fiber accumulation inside the connective tissue underlying the epithelium tissue, are the factors that lead to the establishment and evolution of the palatal pattern. The palatal pattern has a unique direction because collagen fibers migrate antero-posteriorly across each rugae's basal region [11, 12]. Hydrophilic glycosaminoglycan, the main component of plica palatinae, encourages tissue swelling and helps maintain the rugae pattern [13].

With age, the rugae pattern's length and breadth increase in both males and females, but they cease to grow after the somatic growth is finished [14].

Fatima et al. asserted that after the age of ten, the anterior rugae's length does not increase, while other characteristics such as direction, shape, and unification remain constant throughout an individual's life. [15]. Oral sucking, taste perception, food crushing, swallowing, pronunciation — especially the "sh" and "s" sounds — and

medicolegal identification are all made easier by rugae ridges [16, 17].

In terms of the palatal rugae's anatomical location within the head's structure inside the mouth, they are shielded from postmortem injury by the tongue, lips, cheeks, lips, fat, teeth, and bone, as well as by prosthetic devices [10]. The morphology of rugae patterns is unaffected by injuries, chemicals, acids, wounds, dentition eruption and dropping, or lifethreatening conditions; it remains intact even after third-degree burns, though tooth extractions slightly shift its position [18].

A number of factors, such as persistent pressure from orthodontic treatment or dentures, and intense finger sucking throughout development, can result in changes to the palatal pattern. The third rugae pairs provide the most stable reference, and the rugae are less susceptible to alterations caused by tooth movement the more posterior they are [19]. Additionally, it has been reported in the literature that once remains were preserved for at least seven days, 77% of human cadavers and 93% of burn victims showed no surface alterations [20].

In 1911, Gloria developed the first technique for classifying palatal rugae, and there are two ways to classify the rugae pattern indicating the quality and length of rugae in relation to teeth. He also made a distinction between simple or primitive and highly sophisticated rugae.

The rugae were separated into four categories [3] based on their form. Curved rugae were delicately curved and had a crescent form. Wavy: If there is a slight curvature at the start or finish of curved rugae. Straight: They travel from their starting point to their ending point in a straight line. Circular: Rugae were defined as those that create a distinct, continuous ring.

Analyzing of palatal rugae also known as rugoscopy, involves various methods in forensic odontology. Here are some common ways to analyze palatal rugae, along with sources for further reference:

- 1) Photographic superimposition — Overlaying photographs of palatal rugae for comparison [21].
- 2) Dental casts and impressions — Creating casts or impressions of palatal rugae for detailed examination [1].
- 3) Digital imaging and computer software — Utilizing computer software for digital analysis and comparison [22].
- 4) Landmark analysis — Identifying specific landmarks on palatal rugae for quantitative analysis [23].
- 5) Comparison with reference databases — Comparing palatal rugae patterns with established databases for identify [24].

MATERIALS AND METHODS

Study design and participants

At the University of Basrah's College of Dentistry, an observational cross-sectional study was carried out. The duration for sample collection was between November 2023 and March 2024. A sample of 250 patients from the clinics of the College of Dentistry in Basra. The samples equally divided between males and females (125 males and 125 females). The samples divided into four age groups 10–20,

20–40, 40–60 and 60–80 years. All participants met the following criteria:

- no dental anomalies;
- no past medical history of serious illness or trauma
- no prior experience with orthognathic surgery;
- no prior orthodontic care;
- absence of extensive restorative treatments (bridges, crowns, etc.);
- no severe malocclusion, such as a crossbite or open bite.

Sample size

The sample size was calculated based on estimating proportions of palatal rugae patterns using a confidence level of 95% and a margin of error of 5%. As no prior prevalence data were available for the studied population, a prevalence (p) of 50% was assumed to obtain the maximum sample size. The sample size was calculated using the formula:

$$n = Z^2 \cdot p \cdot (1-p) / d^2,$$

where n – required sample size, Z – 1.96 (for 95% confidence level), $p=0.5$, $d=0.05$ (margin of error).

The calculated minimum sample size was 384. However, due to time and resource limitations, a total of 250 subjects (125 males and 125 females) were included in the study, which was considered adequate for statistical analysis.

Procedures

A thorough procedure was used to get study participants' maxillary arch impressions. Following the completion of a medical history and the exclusion of certain cases, the study was carried out on patients who did not have any dental anomalies, a history of serious illness or trauma, a history of orthognathic surgery, a history of prior orthodontic treatment, or a history of extensive restorative procedures (such as crown and bridge work). Participants with significant malocclusion, such as open bite and crossbite, were not allowed to participate in the study.

Irreversible hydrocolloid materials and addition silicone selected for capturing maxillary arch impressions.

These materials were chosen for their ability to provide precise impressions while ensuring patient comfort. Disposable trays were carefully chosen based on the size and shape of each subject's maxillary arch, guaranteeing a proper fit and minimizing discomfort during the impression-taking process.

Following manufacturer guidelines, mixed the water-to-powder ratio for alginate materials. The alginate powder was measured using a scoop, and the water proportion was precisely measured using a cylindrical plastic measuring cylinder. Distilled or demineralized water as needed to account for changes in water quality. In a clean, flexible rubber bowl, the calculated amount of water is added to start the mixing process. Next, the appropriately sized powder is added. To create a homogenous mixture, a widebladed spatula was used for quick mixing. When removed from the bowl, the resultant mixture was creamy and did not leak off the spatula. For the graduation research project, accurate maxillary arch impressions were taken by following this thorough process. This contributed significantly to dental research by guaranteeing the validity and dependability of the study's conclusions about the morphology and patterns of the palatal rugae.

Data analysis

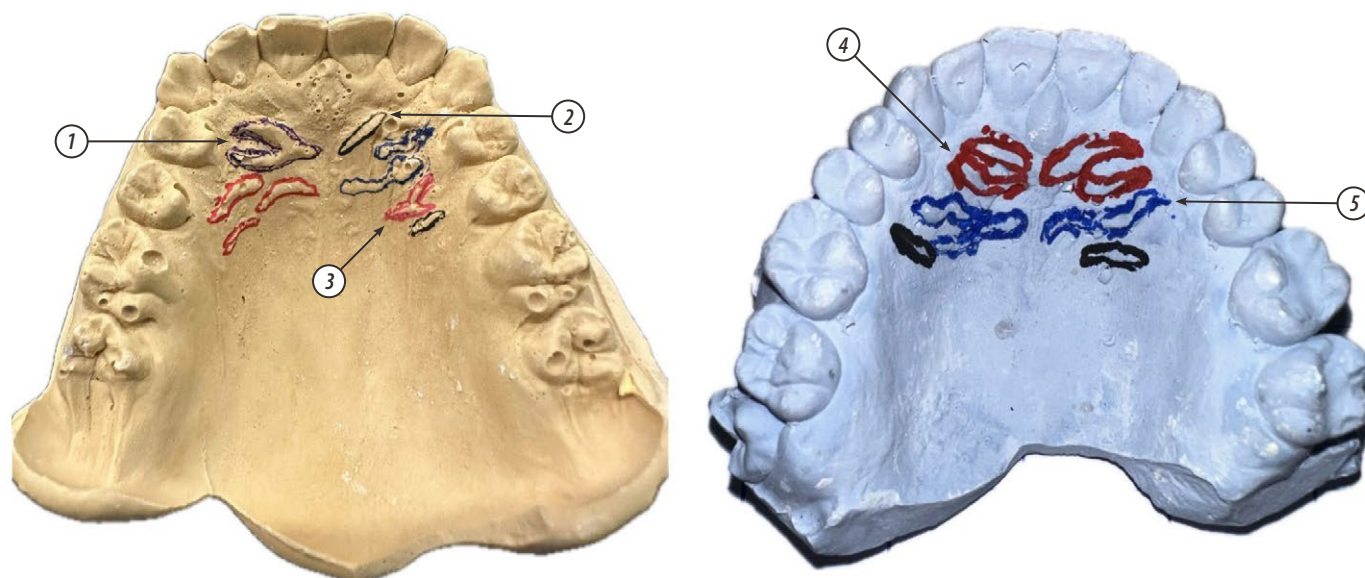
Numerous techniques were used to analyze the patterns of the palatal rugae on the casts, including:

- qualitative rating based on morphology (form);
- quantifiable metrics like ridge count and branching patterns.

Statistical analysis was then used to compare the distribution and frequency of rugae patterns in males and females.

Determination of rugae area

A method for figuring out the rugae area was created for the graduation research project. The first step in the procedure was to carefully choose premium markers that would produce markings that were both consistent and clear. For ease of recognition and classification, each rugae shape was



Determination of rugae area: 1 — Diverge rugae, 2 — Straight rugae, 3 — Converge rugae, 4 — Curved rugae, 5 — Wavy rugae

given a specific color, such as blue for wavy, red for curved, etc. By making it easier to visually distinguish between rugae shapes, this color-coding method expedited the sorting process and reduced errors. We made sure that a wide variety of marker options, such as various tip sizes and ink formulas, were available. The selection of markers was focused on their capacity to create durable, clear markings as well as their compatibility with the impression material. Team members were given particular rugae forms to mark in order to efficiently divide the work. Training sessions were held before marking to guarantee consistency in marking methods and compliance with color coding guidelines. Issues were resolved using methodical approaches to problem-solving during the marking process. To clear up any confusion or disagreements over the definition of rugae forms, professional consultations with seasoned academics and physicians were sought.

Following marking, each cast was given a special identification number so that the matching rugae markings could be tracked during the analytical stage. The highlighted data was arranged and analyzed using specialized spreadsheet software, which made statistical analysis and data sorting more effective. Rigorous quality assurance measures were implemented to ensure the accuracy and reliability of the marked data. To confirm the markings' consistency and reduce any possible mistakes or inconsistencies, frequent crosschecks and validations were carried out. We were able to precisely identify the rugae area in the graduation study project while upholding the highest standards of accuracy and scientific rigor by following this thorough procedure (see the figure).

Table 1. Statistical analysis of difference rugae shape according to gender using Chi-square test

Type of rugae	Males			Females			Total	p
	abs.	%	95% CI	abs.	%	95% CI		
Straight	170	46.7	0.12–0.95	194	53.3	0.22–0.86	364	0.440
Curved	227	48.6	0.23–0.55	240	51.4	0.19–0.92	467	0.110
Wavy	202	48.4	0.88–1.25	215	51.6	0.36–0.74	417	0.582
Circular	49	54.4	1.81–2.59	41	45.6	0.59–1.41	90	0.520
Converge	28	45.9	0.23–0.88	33	54.1	0.46–0.93	61	0.494
Diverge	102	54.3	0.43–1.55	86	45.7	0.65–0.99	188	0.510
Total	776			810			1587	

Table 2. Distribution of different rugae number according to age groups

Type of palatal folds	Mean age, years	Age groups, years								Total	p
		60–80		40–60		20–40		10–20			
		abs.	%	abs.	%	abs.	%	abs.	%		
Straight	38.1±9.2	63	22.27	122	33.51	143	39.28	18	4.94	364	0.520
Curved	40.2±9.5	114	24.43	150	32.11	183	39.18	20	4.28	467	0.523
Wavy	35.3±11.6	100	23.98	131	31.43	168	40.28	18	4.31	417	0.364
Circular	39.3±12.5	16	17.77	31	34.44	37	41.12	6	6.67	90	0.421
Converge	32.7±15.4	7	11.49	21	34.42	30	49.18	3	4.91	61	0.331
Diverge	35.4±11.5	43	22.87	56	29.97	81	43.09	8	4.25	188	0.705
Total rugae	36.3±10.5	363	22.87	509	32.25	641	40.39	74	4.56	1587	0.738

Statistical analysis

We used two main statistical methods to evaluate possible sex differences in rugae quantity and pattern: Unpaired *t*-test: Using this technique, the means of two separate groups males and females were compared with respect to the quantity of rugae. It enabled us to ascertain whether the two groups differed in a way that was statistically significant. Chi-square test: This test was employed to analyze categorical data and assess the correlation between rugae pattern (i.e., Straight, Circular, Curved, Wavy, Unified) and (male/female). Cramér's *V*-test used to calculate size effects. It allowed us to determine whether male and female rugae patterns differed significantly.

RESULTS

1. The relation between rugae shape and gender

The total number of rugae was 1587 divided as follows: 776 in males and 810 in females. The gender distribution of rugae types does not differ statistically significantly (*p*>0.05; table 1). The proportion of females with curved rugae is slightly higher than that of men, the proportion of females with straight rugae is slightly higher than that of males, and the proportion of females with wavy rugae is slightly higher than that of males. However, males are more likely than females to be round and divergent.

Male and female palatine rugae were most frequently curved, followed by wavy, straight, diverging, circular, and convergent shapes. Men had a much higher frequency of the diverging form (102) than females (86), however, compared to men (227), females showed a substantially greater total number of curved rugae (240).

2. The relation between rugae shape and age group

Total number of rugae among this age groups were 1587. The age group with largest number of rugae was 20–40 years with 641 rugae, followed by 40–60 years with 509, 60–80 years with 363, and 10–20 years with 74 rugae. The distribution of rugae by age group does not change significantly (*p*>0.05; table 2).

Curved shapes were most prevalent in the 10–20 age range, followed by straight and wavy shapes in equal proportion. Convergence was the least common shape. Curved shapes were most prevalent in the 20–40 age range, followed by wavy and straight shapes; convergent shapes were least common. Curved shapes were the most popular among those aged 40 to 60, followed by straight and wavy forms; convergent shapes were the least popular. Curved shapes were most prevalent among the 60–80 age group, followed by straight and wavy forms; convergent shapes were least common.

3. Distribution parameters

The mean number of palatine rugae per individual was 6.35. Females showed a slightly higher mean number of rugae (6.48) compared to males (6.21). Standard deviations could not be calculated due to the absence of individual-level data.

4. Size effect

Cramér's V-analysis revealed a strong association between rugae type palatal folds and the number of folds ($V=0.6$). Straight and curved fold patterns demonstrated moderate associations ($V=0.5$ and 0.4 respectively), while circular folds showed a weak association ($V=0.2$). Wavy, converging, and diverging fold types exhibited very weak associations ($V=0.1$; table 3).

DISCUSSION

The findings of the present study demonstrate the diversity of palatal rugae patterns that exist within a sample obtained from the Dental College of the University of Basra, Iraq. Based on these findings, the establishment of a database for recording palatal rugae patterns could be initiated to support forensic identification purposes [25].

A total of 250 dental impressions were collected from 125 male and 125 female participants, including patients seeking dental treatment and dental students undergoing clinical training at the Prosthodontics Clinic of the Dental College, University of Basra. The distribution of different rugae patterns across various age and gender groups was evaluated. In addition, the potential application of palatal rugae patterns for sex determination was assessed. Although the exact causes underlying differences in rugae patterns between males and females remain unclear, several contributing factors have been proposed, including hormonal influences [26], genetic determinants [27], and variations in facial growth patterns [28].

Age estimation using palatal rugae patterns requires a detailed analysis of rugae morphology and comparison with established age-related trends. Such comparisons enable the inference of age groups based on characteristic rugae distributions. For instance, a cast exhibiting a high percentage of curved rugae and lower proportions of straight, wavy, and convergent rugae is more likely to belong to the 10–20-year age group, in which curved rugae are most prevalent. A predominance of curved rugae accompanied by notable proportions of wavy and straight rugae suggests the 20–40-year age group. Similarly, higher percentages of curved and wavy rugae with fewer straight rugae are indicative of individuals aged 40–60 years. In contrast, casts displaying the highest proportion of curved rugae with comparatively lower percentages of wavy and straight patterns are more suggestive of the 60–80-year age group.

Among the various palatal rugae patterns, the total number of rugae demonstrated the strongest correlation with rugae morphology. Straight and curved patterns showed moderate correlations, whereas circular, wavy, convergent, and divergent patterns exhibited weak to very weak associations.

Age-related bone remodeling is a continuous physiological process that affects the entire skeleton, including

Table 3. Size effect analysis of palatal folds according Cramér's V-test

Type of palatal folds	No. of folds	V	Strength of association
Straight	364	0.5	Relatively strong
Curved	467	0.4	Relatively strong
Wavy	417	0.1	Weak
Circular	90	0.2	Moderate
Converge	61	0.1	Weak
Diverge	188	0.1	Weak
Rugae	1587	0.6	Strong

the craniofacial bones. Changes in the shape and structure of the hard palate due to bone remodeling may influence the morphology and arrangement of palatal rugae [29]. Additionally, age-related factors such as tooth loss, dental restorations, and alterations in occlusion may indirectly affect rugae patterns [30]. Changes in collagen content, tissue elasticity, and vascularization associated with aging can also alter the oral soft tissues, including the palatal mucosa, thereby influencing rugae appearance [31]. Functional changes related to mastication, swallowing, and oral hygiene practices may further contribute to these variations, although their full impact remains unclear [23]. Degenerative conditions associated with aging, such as periodontal disease and oral mucosal atrophy, may also compromise the integrity of palatal rugae and surrounding tissues [32].

The results of the present study revealed that curved rugae were the most prevalent pattern in both males (29.2%) and females (29.6%). These findings are consistent with those reported by A.M. Abdellatif et al. (2011), who examined palatal rugae patterns in children from Saudi Arabia and Egypt and found curved rugae to be most common among Egyptian children, followed by wavy and straight patterns, while wavy rugae predominated among Saudi children [33]. Similarly, S. Choudhari and T.N.U. Maheswari et al. (2020) reported curved rugae as the most prevalent pattern (34%) in both sexes in an Indian population [34]. A. Indira et al. (2012) also observed curved rugae as the most frequent pattern in males (33.2%) and females (29.5%) in Bengaluru, India [35]. Comparable findings were reported by A. Kumar et al. (2021), who identified curved rugae as the predominant pattern (27%) in both genders [36].

In contrast, M. Sheikhi et al. (2018) reported straight rugae as the most common pattern in an Iranian population, followed by wavy and curved forms [26]. M. Selvamani et al. (2015) found wavy rugae to be predominant in both males and females in Kerala, South India, followed by curved and straight patterns [37]. S. Kallianpur et al. (2011) reported wavy rugae as the most prevalent pattern among Indian and Nepalese populations, consistent with findings in Caucasian and Australian populations, with curved rugae ranking second [38].

These variations suggest that palatal rugae patterns exhibit geographic and population-specific characteristics. Unlike several previous studies in which wavy rugae predominated, the present study demonstrated a higher prevalence of curved rugae in the Basrah population. Therefore, when comparing dental casts from different populations, the dominant rugae pattern should be carefully considered.

A higher proportion of curved rugae may indicate a greater likelihood that a cast originated from the Basrah region. Further research in diverse populations may enhance the forensic utility of palatal rugae patterns for human identification.

Clinical implication and recommendations

Age-related changes in palatal rugae morphology appear to be associated with physiological processes such as bone remodeling, dental status, and alterations in oral soft tissues. The distribution of rugae patterns across different age groups suggests that palatal rugae may provide supportive information for age estimation when combined with other forensic indicators. Overall, the findings support the potential forensic value of palatal rugae as a supplementary tool for personal identification, particularly in population-specific contexts. The establishment of a standardized database for palatal rugae patterns in the Iraqi population may enhance their application in forensic investigations. However, further studies involving larger sample sizes and diverse populations are recommended to improve reliability and strengthen the role of palatal rugae analysis in forensic science.

Study limitations

The sample size of 250 participants, drawn from a single institution — the University of Basra — may limit the generalizability of the findings to other populations or regions in Iraq. Although multiple age groups were included, the relatively small number of participants within each group may reduce the statistical power for age-related comparisons. Additionally, the study population consisted mainly of dental students

and patients, which may not fully represent the broader Basra population in terms of ethnicity, socioeconomic status, or oral health. Environmental and lifestyle factors, such as diet or oral habits, which could influence rugae patterns, were not assessed. The classification of rugae patterns relied on visual examination, introducing potential observer bias despite the use of standardized methods. Furthermore, the cross-sectional design captures rugae patterns at a single point in time, preventing analysis of longitudinal changes or definitive conclusions about age-related causes. Finally, while genetic and hormonal influences on rugae patterns were discussed, no direct measurements were taken, limiting the ability to draw conclusions about the mechanisms underlying sex differences.

CONCLUSION

This study demonstrates that palatal rugae patterns vary with age and sex in a population from the University of Basra, Iraq, with curved rugae being the most prevalent pattern in both males and females. The observed variations highlight the influence of biological and age-related factors on rugae morphology. These findings support the potential use of palatal rugae as a supplementary tool for age estimation and personal identification in forensic practice. Establishing a population-specific rugae database may further enhance their forensic applicability.

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