



# Evaluation of the Effects of Palatal Rugae on the Determination of Sex and Age in a Group of Children: A Cross-Sectional Study

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## ABSTRACT

**Aim:** This study aimed to evaluate age- and sex-related variations in palatal rugae and to determine whether digital maxillary scans could detect distinctive patterns in rugae count, position, length, shape, and unification.

**Materials and Methods:** Plaster casts from 180 children (90 boys, 90 girls; aged 5-6, 7, 8, 9, 12, 13 years) were digitized with a scanner. The rugae were measured in terms of their number, position, length, shape and unification. The statistical analysis comprised the application of the Mann-Whitney U and Kruskal-Wallis tests to evaluate age- and sex-related differences. Significance was set at 0.05 and Bonferroni-adjusted thresholds were employed in instances of multiple comparisons.

**Results:** The counts (right, left, total) were comparable across age groups for both sexes and overall ( $p>0.0083$ ), and there was no difference between boys and girls within any age group ( $p>0.0071$ ). The rugae position, length and shape exhibited no evidence of variation related to sex or age-by-sex interactions ( $p>0.05$ ).

**Conclusion:** Within the limitations of this cross-sectional study, palatal rugae characteristics showed no statistically significant age- or sex-related differences in this pediatric sample. These findings suggest that palatal rugae may have limited utility for age estimation when used alone, and their forensic relevance should be clarified in further longitudinal and multi-population studies.

**Keywords:** Forensic dentistry, forensic identification, pediatric dentistry, palatal anatomy, palatal rugae

## Introduction

Forensic identification is an interdisciplinary field which aims to accurately and reliably identify individuals, particularly following traumatic events. Over time, the methods used in this field have diversified and some characteristic features of individuals' biological structures have started to be utilized. Alongside methods such as fingerprinting, dental records and DNA analysis, intraoral

soft tissue structures are one of the alternatives that have attracted attention (1-6).

Palatal rugae are anatomical structures located in the anterior region of the hard palate which appear as ridges on the mucosa. Formed during embryonic development, these structures are genetically determined and remain largely constant throughout life (7-10). Except in cases of trauma, ageing or certain surgical procedures, there is no significant

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change to their morphological structure. Therefore, palatal rugae are considered to be one of the structures which bear traces of individual differences (5,6-9). It has been reported that the shape, unification, length and alignment of rugae palatinae differ between individuals, being influenced by genetic and environmental factors. It has also been suggested that variables such as gender, age and ethnicity may affect these structures. This makes it worthwhile to evaluate palatal rugae as a biometric marker (3-6,9-11).

Advances in technology mean that digital models are increasingly being used to evaluate palatal rugae. Analyses performed on models obtained with three-dimensional scanners provide more objective and reproducible results than traditional methods. In particular, the accuracy of measurements made in a digital environment increases when examining morphologic structures in detail, providing researchers with more reliable data (12-14). Previous studies conducted in pediatric populations have also suggested that palatal rugae may show population-specific morphological characteristics and may be investigated as potential adjunctive markers in forensic identification and sex-related assessment. In this context, understanding the structure and variations of palatal rugae has gained an important place in both clinical and forensic applications. Findings in the literature show that these anatomical structures are remarkable in terms of reflecting individual differences and can be considered as a complementary element in forensic identification processes (5-11).

Therefore, the aim of this study was to compare palatal rugae characteristics across pediatric age groups and between sexes, and to determine whether the number, position, length, shape, and unification of the palatal rugae identified on digital maxillary scans may provide features of potential value in forensic dentistry. By clarifying the stability and variability of these characteristics in children, this study also sought to explore the potential of palatal rugae as supportive anatomical markers for human identification and age- and sex-related assessment when conventional forensic methods are limited. It was hypothesized that palatal rugae may serve as supportive anatomical markers in forensic dentistry in children.

## Materials and Methods

### Study Design, Ethical Approval, Statements and Checklists

This study had a cross-sectional study design. Ethical approval for the present study was provided by the Clinical Research Ethics Committee of Ankara University Faculty

of Dentistry (approval number: 6/8, date: 21.03.2018). This study was conducted in accordance with the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) checklist for cross sectional studies (15).

### Eligibility Criteria

Pediatric dental patients meeting the following inclusion criteria were included in the present study:

- Patient aged 5-6, 7, 8, 9, 12 and 13,
- Patients without mental retardation,
- Patients in American Society of Anesthesiologists (ASA) 1 or ASA 2 according to the ASA classification.

However, those patients meeting any of the following exclusion criteria were not included:

- Patients with physical or mental disabilities,
- Patients with cleft/palate lip,
- Patients with a history of orthodontic treatment or orthognathic surgery,
- Patients with malocclusion or dental arch asymmetries,
- Patients with a thumb sucking habit,
- Patients with bone or soft tissue overhangs in the palate,
- Patients allergic to the impression material,
- Patients with the loss of at least one tooth except for physiological shedding.

Variables related to eligibility, including ASA classification, medical history, previous orthodontic treatment history, and other exclusion criteria, were determined based on anamnesis forms and patient/parent-reported information obtained during the clinical examination. Turkish origin was identified according to the demographic information recorded for the participants, and only children of Turkish origin were included in this study. In addition, the 10-11-year age group was not included because this transitional period is associated with accelerated maxillary growth, increased interindividual variability, and a higher frequency of orthodontic treatment initiation, all of which could reduce group homogeneity.

### Sample Size Calculation

Sample size calculation was performed using G\*Power software (version 3.0.10; Franz Faul, Universität Kiel, Kiel, Germany). Based on the primary between-group comparison, an assumed effect size of 0.70, a statistical power of 90%, and a Bonferroni-adjusted type I error level of 3.125% for multiple comparisons were used. According to this analysis, the minimum required sample size was 15

girls and 15 boys per age group. Accordingly, a total of 180 children were included across the six predefined age groups.

### **Clinical Procedures and Rugae Analysis**

All rugae assessments were performed by a single examiner using standardized evaluation criteria, and intra-examiner reliability was assessed by repeated measurements at one-week intervals. Dental impressions were taken from the upper jaw of the patients included in this study with the impression trays selected for each patient, and plaster models were obtained. After that, digital models were obtained in .stl format using an extraoral model scanner device (Sirona inEos x5, Sirona Dental GmbH, Wals Bei Salzburg, Austria) by scanning the plaster models. On the obtained digital models, characteristics such as number, position, length, shape and unification of the rugae were evaluated using Integrate Rugoscopy Chart (16) and 3D-DOCTOR software (Solidworks, United States). Subsequently, the data were recorded for further statistical analysis.

### **Number Analysis of Rugae**

On the digital models, the contours of the palatal rugae were identified separately on the right and left sides of the midline. In this study, the term “number of rugae” refers to the count of individual palatal rugae identified on each side, and the total number of rugae for each patient was calculated as the sum of the right and left sides. Subsequently, the rugae were counted and recorded for each patient. The number analysis performed on the digital models was repeated twice at a one-week interval, and reliability was evaluated using the kappa test ( $\kappa=0.95$ ).

### **Position Analysis of Rugae**

5 different areas were determined by using 6 reference lines in order to determine the position of the rugae on the palate and the positions of the rugae were recorded. If the rugae was long enough to be located in more than one region, the region where the larger part of the rugae was located was recorded. The position analysis was repeated twice with a one-week interval and reliability was evaluated with the Kappa test ( $\kappa=0.91$ ). The reference lines from which the rugae position was determined are given below.

1. Horizontal line passing through the palatal cervical third of the central incisors.
2. Horizontal line extending from the mesial of the right lateral incisor to the mesial of the left lateral incisor.
3. Horizontal line extending from the mesial of the right canine to the mesial of the left canine.

4. Horizontal line extending from the mesial of the right 1<sup>st</sup> premolar to the mesial of the left 1<sup>st</sup> premolar.

5. Horizontal line extending from the mesial of the right 2<sup>nd</sup> premolar to the mesial of the left 2<sup>nd</sup> premolar.

6. Horizontal line extending from the distal of the right 2<sup>nd</sup> premolar to the distal of the left 2<sup>nd</sup> premolar.

Accordingly, zone A was the area between lines I and II, zone B was the area between lines II and III, zone C was the area between lines III and IV, zone D was the area between lines IV and V, and zone E was the area between lines V and VI.

### **Length Analysis of Rugae**

To determine the rugae length, the beginning and the end points of each rugae were marked on the digital model and the length between the two points was measured by the software. The measured lengths were recorded in 3 categories as primary, secondary and fragmentary. The length measurements performed on the digital models were repeated twice at one-week intervals and reliability was evaluated with the Kappa test ( $\kappa=0.89$ ). The abovementioned categories of rugae measurements are explained below. Rugae shorter than 2 mm were ignored (Figure 1).

Primary rugae: 5-10 mm and above

Secondary rugae: 3-5 mm

Fragmentary rugae: 2-3 mm

### **Shape Analysis of Rugae**

On digital models, palatal rugae were examined in 6 categories as curved, wavy, straight, circular, angled, and fused (X-shaped). Shape assessment was performed by standardized observer-based evaluation of the digital models according to the predefined morphological categories of the Integrated Rugoscopy Chart, rather than by an automated software-based analysis. The number of each rugae shape in each patient was recorded. Shape analyses performed on the digital models were repeated twice at one-week intervals, and reliability was evaluated using the Kappa test ( $\kappa=0.88$ ) (Figure 2).

### **Unification Analysis of Rugae**

Unification analysis was performed when two rugae were joined either at their origin or at their terminal end. This feature was evaluated only for angled rugae. Rugae were classified as divergent when they originated from a common point at the midline and then branched apart, or as convergent when they arose from different origins

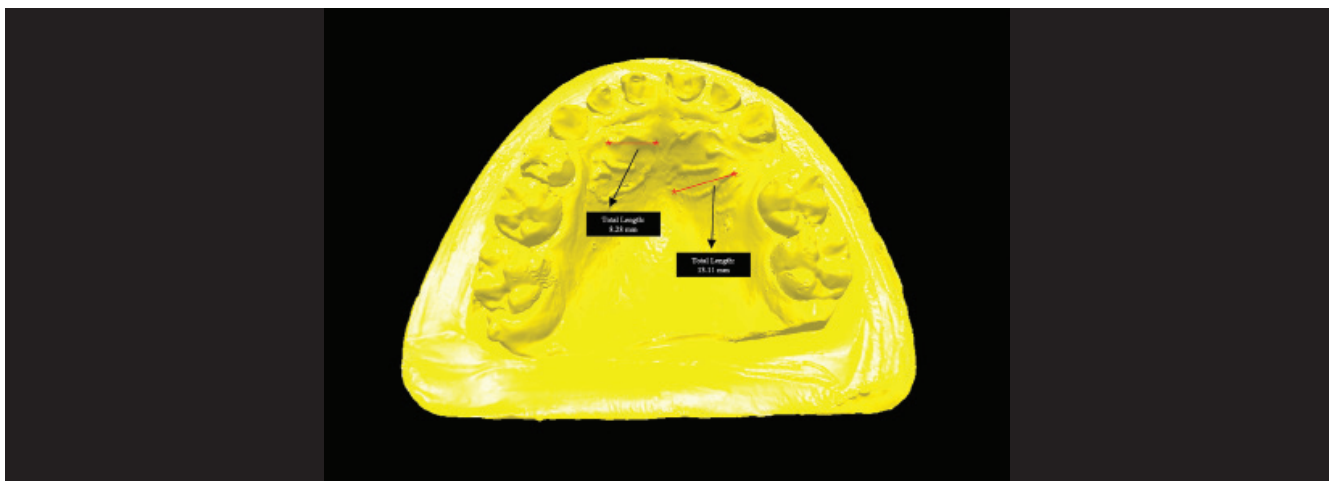
and subsequently joined. The unification pattern of angled palatal rugae was determined on the digital models and recorded for each patient. Unification analyses performed on the digital models were repeated twice at one-week intervals, and reliability was evaluated using the Kappa test ( $\kappa=0.88$ ) (Figure 3).

### Statistical Analysis

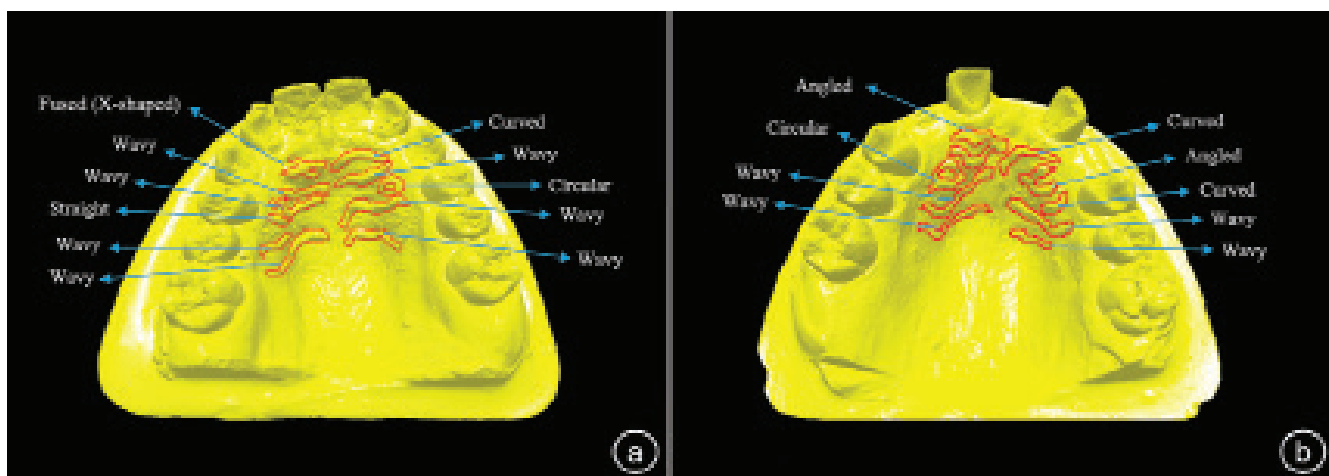
Data analysis was performed in IBM SPSS Statistics 17.0 (IBM Corporation, Armonk, NY, USA). Whether the distribution of discrete numerical variables was close to normal was investigated with the Kolmogorov-Smirnov test, and the homogeneity of the variances was investigated with the Levene test. Descriptive statistics are expressed as mean  $\pm$  standard deviation for discrete numerical variables, while categorical variables are expressed as the number of observations and percentages.

The Mann-Whitney U test was used to analyze whether there was a statistically significant difference between the sexes in terms of number, position, shape, length and unification of the rugae. Whether there was a statistically significant difference between age groups in terms of the same characteristics was analyzed with the Kruskal-Wallis test. If the results of the Kruskal-Wallis test statistics were found to be significant, the situations causing the statistical differences were determined by using Conover's multiple comparison test.

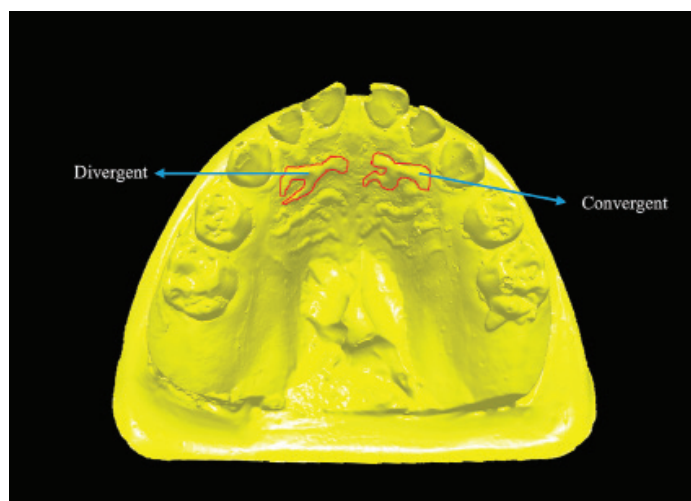
The significance of the difference in rugae numbers between the right and left sides within each subgroup was analyzed with the Wilcoxon test. Unless otherwise stated, results for  $p<0.05$  were considered statistically significant. However, in all possible multiple comparisons, Bonferroni Correction was made to check for Type-I errors.



**Figure 1.** Measurement of the length of the rugae on the right and left sides on the digital model of the upper jaw of a 7-year-old male patient



**Figure 2.** Rugae shape analysis on digital models of the upper jaws. **a)** Digital model of a 12-year-old female patient showing the identified rugae shapes. **b)** Digital model of a 9-year-old female patient showing the identified rugae shapes.



**Figure 3.** Analysis of the unification characteristics of angulated rugae on the digital model of the upper jaw of a 5-6-year-old female patient

## Results

A total of 180 children were included in this study, comprising six age groups (5-6, 7, 8, 9, 12, and 13 years), with 15 girls and 15 boys in each group. Six age groups (5-6, 7, 8, 9, 12 and 13) were determined in order to evaluate any changes in the number, position, shape, length and unification of palatal rugae with regards to the sex and age of the children. A total of 180 patients, 15 girls and 15 boys in each age group, were included in this study.

In comparisons between the sexes, the total number of rugae was found to be higher in girls ( $n=737$ ) than in boys ( $n=726$ ). When the number of palatal rugae in the right and left halves of the palate was evaluated within the sexes, the number of rugae in the left half was higher in girls (right=364, left=373), while the number of rugae in the right half was higher in boys (right=365, left=361). However, when the age group was kept constant, there was no statistically significant difference between girls and boys in terms of right, left and total rugae ( $p>0.025$ ) (Table I).

When the number of rugae in the right and left halves were compared for girls and boys in all age groups, there was no statistically significant difference between the number of rugae in the right and left halves in both sexes ( $p>0.0036$ ). When the total number of rugae in each age group was compared, it was observed that the number of rugae was higher in girls in the 5-6 (girls=124, boys=122), 7 (girls=130, boys=120) and 13 (girls=122, boys=113) age groups, and in boys in the 9 (girls=118, boys=127) and 12 (girls=121, boys=122) age groups, while the number of rugae in both sexes was equal in the 8 (girls, boys=122) age group. However, there was no statistically significant difference in the mean number of rugae between boys and girls in each age group ( $p>0.0071$ ) (Table II).

When the palatal rugae in the right and left halves were compared in terms of position for girls, it was observed that the number of rugae in positions C (right=88, left=89) and D (right=161, left=169) was higher in the left half, while the number of rugae in position E (right, left=115) was

**Table I.** Distribution of palatal rugae in the right and left halves between the sexes

Side	Girls		Boys		Statistics $p^{1*}$
	n (%)	Mean $\pm$ SD	n (%)	Mean $\pm$ SD	
Right	364 (49.4)	4.04 $\pm$ 0.72	365 (50.3)	4.06 $\pm$ 0.72	0.915
Left	373 (50.6)	4.14 $\pm$ 0.70	361 (49.7)	4.01 $\pm$ 0.76	0.234
$p^{1*}$	-	0.160	-	0.547	-
Total	737 (50.4)	8.19 $\pm$ 1.24	726 (49.6)	8.07 $\pm$ 1.30	0.470

<sup>1</sup>: Mann-Whitney U test, <sup>\*</sup>: Wilcoxon Signed-Rank test, <sup>\*</sup>: Results were considered statistically significant for  $p<0.025$  according to Bonferroni correction except for the comparison between girls and boys in terms of total number of rugae  
n: Number of rugae, %: Proportion of total number of rugae, SD: Standard deviation

**Table II.** Distribution of palatal rugae on the right and left according to sex and age groups

Age groups (years)	Girls-Right		Girls-Left		Boys-Right		Boys-Left		Girls-Total		Boys-Total		Statistics	
	n (%)	Mean±SD	n (%)	Mean±SD	n (%)	Mean±SD	n (%)	Mean±SD	n (%)	Mean±SD	n (%)	Mean±SD	p <sup>†</sup>	p <sup>‡</sup>
5-6	62 (17.0)	4.13±0.74	62 (16.6)	4.13±0.64	62 (17.0)	4.13±0.74	60 (16.6)	4.00±0.76	124 (16.8)	8.27±1.28	122 (16.8)	8.13±1.25	0.577	0.713
7	62 (17.0)	4.13±0.83	68 (18.2)	4.53±0.52	60 (16.4)	4.00±0.76	60 (16.6)	4.00±0.76	130 (17.6)	8.67±1.29	120 (16.5)	8.00±1.36	>0.999	0.217
8	60 (16.5)	4.00±0.53	62 (16.6)	4.13±0.74	62 (17.0)	4.13±0.64	60 (16.6)	4.00±0.84	122 (16.6)	8.13±0.99	122 (16.8)	8.13±1.41	0.317	>0.999
9	58 (15.9)	3.87±0.74	60 (16.1)	4.00±0.76	61 (16.7)	4.07±0.80	66 (18.3)	4.40±0.74	118 (16.0)	7.87±1.25	127 (17.5)	8.47±1.36	0.096	0.217
12	60 (16.5)	4.00±0.76	61 (16.4)	4.07±0.80	61 (16.7)	4.07±0.88	61 (16.9)	4.07±0.70	121 (16.4)	8.07±1.44	122 (16.8)	8.13±1.41	>0.999	0.902
13	62 (17.0)	4.13±0.74	60 (16.1)	4.00±0.65	59 (16.2)	3.93±0.59	54 (15.0)	3.60±0.63	122 (16.6)	8.13±1.25	113 (15.6)	7.53±1.06	0.059	0.148
<b>Total</b>	364 (49.4)	4.04±0.72	373 (50.6)	4.14±0.70	365 (50.3)	4.06±0.72	361 (49.7)	4.01±0.76	737 (50.4)	8.19±1.24	726 (49.6)	8.07±1.30	0.547	0.470

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, <sup>†</sup>Wilcoxon Signed-Rank test, results were considered statistically significant for p<0.0071 according to Bonferroni correction, <sup>‡</sup>Mann-Whitney U test, results were considered statistically significant for p<0.0036 according to Bonferroni correction.

equal in the right and left halves. However, when the positions of the palatal rugae in the right and left halves for girls were compared independently of age groups, no statistically significant difference was observed between the rugae positions in the right and left halves (p>0.025) (Table III).

When the palatal rugae in the right and left halves were compared in terms of length for girls, the number of primary (right=323, left=336) and fragmentary (right=2, left=3) rugae were found to be higher in the left half, while the number of secondary (right=39, left=34) rugae was higher in the right half. However, when the lengths of the palatal rugae in the right and left halves for girls were compared independently of age groups, no statistically significant difference was found between the lengths of the rugae in the right and left halves (p>0.025) (Table III).

When the shapes of the palatal rugae in the right and left halves were compared for girls, it was observed that curved (right=78, left=87), wavy (right=223, left=225), circular (right=5, left=7) and straight (right=16, left=17) shaped rugae were more common in the left half, while angled (right=40, left=36) and fused (X-shaped) (right=2, left=1) shaped rugae were more common in the right half. However, when the shapes of the palatal rugae in the right and left halves for girls were compared independently of age groups, no statistically significant difference was observed between the rugae shapes in the right and left halves (p>0.025) (Table III).

When the palatal rugae in the right and left halves were compared in terms of position, the number of rugae in positions C (right=92, left=93) and E (right=112, left=113) was higher in the left half and the number of rugae in position D (right=161, left=155) was higher in the right half for boys. However, when the positions of the palatal rugae in the right and left halves for boys were compared independently of age groups, no statistically significant difference was observed between the rugae positions in the right and left halves (p>0.025) (Table III).

When palatal rugae in the right and left halves were compared in terms of length for boys, it was found that the number of rugae with secondary (right=47, left=37) and fragmentary (right=4, left=3) lengths was higher in the right half, while the number of rugae with primary (right=314, left=321) lengths was higher in the left half. However, when the lengths of the palatal rugae in the right and left halves were compared independently of the age groups for boys, there was no statistically significant difference between the rugae lengths in the right and left halves (p>0.025) (Table III).

**Table III.** Distribution of palatal rugae in the right and left halves in terms of position, length and shape according to sex

Features of rugae	Girls-Right		Girls-Left		Statistics	Boys-Right		Boys-Left		Statistics
	n (%)	Mean±SD	n (%)	Mean±SD	p <sup>†</sup>	n (%)	Mean±SD	n (%)	Mean±SD	p <sup>†</sup>
<b>Position</b>										
C	88 (24.2)	0.98±0.42	89 (23.9)	0.99±0.44	0.763	92 (25.2)	1.02±0.42	93 (25.8)	1.03±0.46	0.796
D	161 (44.2)	1.79±0.66	169 (45.3)	1.88±0.67	0.228	161 (44.1)	1.79±0.61	155 (42.9)	1.72±0.64	0.314
E	115 (31.6)	1.28±0.70	115 (30.8)	1.28±0.78	0.983	112 (30.7)	1.24±0.68	113 (31.3)	1.26±0.80	0.883
<b>Length</b>										
Primary	323 (88.7)	3.59±0.70	336 (90.1)	3.73±0.72	0.099	314 (86.0)	3.49±0.66	321 (88.9)	3.57±0.77	0.490
Secondary	39 (10.7)	0.43±0.56	34 (9.1)	0.38±0.57	0.436	47 (12.9)	0.52±0.62	37 (10.2)	0.41±0.63	0.155
Fragmentary	2 (0.5)	0.02±0.15	3 (0.8)	0.03±0.18	0.655	4 (1.1)	0.04±0.21	3 (0.8)	0.03±0.18	0.564
<b>Shape</b>										
Curved	78 (21.4)	0.87±0.90	87 (23.3)	0.97±0.89	0.316	76 (20.8)	0.84±0.86	83 (23.0)	0.92±0.96	0.312
Wavy	223 (61.3)	2.48±1.13	225 (60.3)	2.50±1.17	0.950	212 (58.1)	2.36±0.85	221 (61.2)	2.46±0.94	0.494
Angled	40 (11.0)	0.44±0.56	36 (9.7)	0.40±0.54	0.465	50 (13.7)	0.56±0.54	36 (10.0)	0.40±0.51	0.024*
Circular	5 (1.4)	0.06±0.23	7 (1.9)	0.08±0.27	0.414	4 (1.1)	0.04±0.21	2 (0.6)	0.02±0.15	0.317
Straight	16 (4.4)	0.18±0.44	17 (4.6)	0.19±0.42	0.827	20 (5.5)	0.22±0.44	18 (5.0)	0.20±0.48	0.721
Fused (X-shaped)	2 (0.5)	0.02±0.15	1 (0.3)	0.01±0.11	0.564	3 (0.8)	0.03±0.18	1 (0.3)	0.01±0.11	0.317

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, \*Wilcoxon Signed-Rank test, results were considered statistically significant for p<0.025 according to Bonferroni correction. †Indicates statistical significance

When the shapes of the palatal rugae in the right and left halves for boys were compared in terms of shape; curved (right=76, left=83) and wavy (right=212, left=221) shaped rugae were more common in the left half, while angled (right=50, left=36), circular (right=4, left=2), straight (right=20, left=18) and fused (X-shaped) (right=3, left=1) shaped rugae were more common in the right half. When the shapes of the palatal rugae in the right and left halves were compared independently of age groups for boys, no statistically significant difference was observed between the rugae shapes in the right and left halves ( $p>0.025$ ) except for the statistically significant difference between the distribution of angled rugae in the right and left halves ( $p=0.024$ ) (Table III).

In the distribution of palatal rugae in terms of position according to age groups; it was observed that the number of rugae in position C was highest in the age group of 9 years ( $n=65$ ) and lowest in the age group of 13 years ( $n=54$ ). However, the distribution of the rugae in position C did not show a statistically significant difference between age groups regardless of gender ( $p>0.05$ ) (Table IV).

The rugae located in position D were most common in the 5-6 age group ( $n=121$ ) and least common in the 9 ( $n=96$ )

and 13 ( $n=96$ ) age groups. The number of rugae in position D tended to decrease with increasing age. There was a statistically significant difference ( $p<0.05$ ) between the 5-6 and 9 age groups ( $p=0.003$ ), the 5-6 and 13 age groups ( $p=0.003$ ), the 7 and 9 age groups ( $p=0.019$ ), and the 7 and 13 age groups ( $p=0.020$ ) in terms of the distribution of the rugae in position D between the age groups regardless of gender (Table IV).

The highest number of rugae in position E was found in the 13 age group ( $n=85$ ) and the lowest in the 5-6 age group ( $n=64$ ). However, there was no statistically significant difference in the distribution of the rugae in position E between the age groups regardless of gender ( $p>0.05$ ) (Table IV).

In the distribution of palatal rugae in terms of length according to age groups, it was observed that the highest number of primary rugae was found in the 5-6 years age group ( $n=221$ ) and the lowest number was found in the 13-year age group ( $n=207$ ). The number of primary rugae tended to decrease with increasing age. However, there was no statistically significant difference in the distribution of primary rugae between the age groups regardless of sex ( $p>0.05$ ) (Table V).

**Table IV.** Distribution of palatal rugae in terms of position according to age groups

Position	Age groups						Statistics
C	5-6 years	7 years	8 years	9 years	12 years	13 years	p <sup>†</sup>
n (%)	61 (24.8)	63 (25.2)	59 (24.2)	65 (26.5)	60 (24.7)	54 (23.0)	-
Mean±SD	2.03±0.85	2.10±0.66	1.97±0.85	2.17±0.70	2.00±0.74	1.80±0.89	0.484
D	5-6 years	7 years	8 years	9 years	12 years	13 years	p <sup>†</sup>
n (%)	121 (49.2)	117 (46.8)	108 (44.3)	96 (39.2)	108 (44.4)	96 (40.9)	-
Mean±SD	4.03±0.93 <sup>ab</sup>	3.90±1.09 <sup>c,d</sup>	3.60±1.04	3.20±1.27 <sup>a,c</sup>	3.60±1.10	3.20±0.96 <sup>b,d</sup>	0.012 <sup>*</sup>
E	5-6 years	7 years	8 years	9 years	12 years	13 years	p <sup>†</sup>
n (%)	64 (26.0)	70 (28.0)	77 (31.6)	84 (34.3)	75 (30.9)	85 (36.2)	-
Mean±SD	2.13±1.11	2.33±1.24	2.57±1.38	2.80±1.35	2.50±1.14	2.83±1.15	0.243

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, <sup>†</sup>Kruskal-Wallis test, results were considered statistically significant for p<0.05. <sup>\*</sup>the difference between the 5-6-year age group and the 9-year age group was statistically significant (p=0.003), <sup>b</sup>the difference between 5-6-year age group and 13-year age group was statistically significant (p=0.003), <sup>c</sup>the difference between 7- and 9-year age group was statistically significant (p=0.019), <sup>d</sup>the difference between 7- and 13-year age group was statistically significant (p=0.020). <sup>†</sup>Indicates statistically significance

**Table V.** Distribution of palatal rugae in terms of length according to age groups

Length	Age groups						Statistics
Primary	5-6 years	7 years	8 years	9 years	12 years	13 years	p <sup>†</sup>
n (%)	221 (89.8)	220 (88.0)	216 (88.5)	215 (87.8)	215 (88.5)	207 (88.1)	-
Mean±SD	7.37±1.07	7.33±1.09	7.20±1.21	7.17±0.99	7.17±1.26	6.90±1.06	0.377
Secondary	5-6 years	7 years	8 years	9 years	12 years	13 years	p <sup>†</sup>
n (%)	23 (9.3)	26 (10.4)	27 (11.1)	30 (12.2)	27 (11.1)	24 (10.2)	-
Mean±SD	0.77±0.73	0.87±0.94	0.90±0.99	1.00±0.95	0.90±0.92	0.80±1.06	0.930
Fragmentary	5-6 years	7 years	8 years	9 years	12 years	13 years	p <sup>†</sup>
n (%)	2 (0.8)	4 (1.6)	1 (0.4)	0 (0.0)	1 (0.4)	4 (1.7)	-
Mean±SD	0.07±0.25	0.13±0.43	0.03±0.18	0.00±0.00	0.03±0.18	0.13±0.43	0.452

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, <sup>†</sup>Kruskal-Wallis test, results were considered statistically significant for p<0.05.

Secondary rugae were most common in the 9-year age group (n=30) and least common in the 5-6-year age group (n=23). However, the distribution of secondary rugae did not show a statistically significant difference between the age groups regardless of sex (p>0.05). The highest number of fragmentary rugae was seen in the age groups 7 (n=4) and 13 (n=4), while no fragmentary rugae were seen in the age group 9 (n=0). However, there was no statistically significant difference in the distribution of fragmentary rugae between the age groups regardless of sex (p>0.05) (Table V).

In terms of the distribution of palatal rugae according to shape based on age groups, it was observed that the curved shape was found most frequently in the 9 (n=61), and least frequently in the 5-6 (n=48) and 13 (n=48) age groups. However, there was no statistically significant difference in the distribution of rugae with curved shape between the age groups regardless of sex (p>0.05). The wavy shaped was

seen mostly in the age group of 7 years (n=157) and least often in the age group of 9 years (n=136). However, there was no statistically significant difference in the distribution of wavy shaped rugae between the age groups regardless of sex (p>0.05). It was observed that the highest number of angled rugae was in the age group of 12 years (n=33), and the lowest in the age group of 7 years (n=23) and 13 years (n=23). However, there was no statistically significant difference in the distribution of angled rugae between the age groups regardless of sex (p>0.05) (Table VI).

The highest number of circular shaped rugae were found in the 13 age group (n=7), while no circular rugae were observed in the 5-6 (n=0) and 8 age groups (n=0). However, there was no statistically significant difference in the distribution of angled rugae between the age groups regardless of sex (p>0.05). It was observed that the highest number of straight shaped rugae was in the age group of

**Table VI.** Distribution of palatal rugae in terms of shape according to age groups

Shape	Age groups						Statistics
	5-6 years	7 years	8 years	9 years	12 years	13 years	
<b>Curved</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	48 (19.5)	58 (23.2)	56 (23.0)	61 (24.9)	53 (21.8)	48 (20.4)	-
Mean±SD	1.60±1.30	1.93±1.57	1.87±1.53	2.03±1.43	1.77±1.61	1.60±1.10	0.851
<b>Wavy</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	156 (63.4)	157 (62.8)	155 (63.5)	136 (55.5)	138 (56.8)	139 (59.1)	-
Mean±SD	5.20±1.58	5.23±1.48	5.17±1.95	4.53±1.66	4.60±1.45	4.63±1.52	0.323
<b>Angled</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	28 (11.4)	23 (9.2)	24 (9.8)	31 (12.7)	33 (13.6)	23 (9.8)	-
Mean±SD	0.93±0.83	0.77±0.90	0.80±0.92	1.03±0.89	1.10±0.99	0.77±0.82	0.593
<b>Circular</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	0 (0.0)	3 (1.2)	0 (0.0)	6 (2.4)	2 (0.8)	7 (3.0)	-
Mean±SD	0.00±0.00	0.10±0.31	0.00±0.00	0.20±0.48	0.07±0.25	0.23±0.63	0.076
<b>Straight</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	12 (4.9)	9 (3.6)	9 (3.7)	11 (4.5)	14 (5.8)	16 (6.8)	-
Mean±SD	0.40±0.67	0.30±0.60	0.30±0.65	0.37±0.56	0.47±0.90	0.53±0.90	0.893
<b>Fused (X-shaped)</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	2 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.2)	2 (0.9)	-
Mean±SD	0.07±0.25	0.00±0.00	0.00±0.00	0.00±0.00	0.10±0.31	0.07±0.25	0.166

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, <sup>†</sup>Kruskal-Wallis test, results were considered statistically significant for p<0.05.

13 (n=16) and the lowest in the age groups of 7 (n=9) and 8 (n=9). However, there was no statistically significant difference in the distribution of straight shaped rugae between the age groups regardless of sex (p>0.05). Fused (X-shaped) rugae was found mostly in the age group of 12 (n=3), while no fused (X-shaped) rugae was observed in the age groups of 7 (n=0), 8 (n=0) and 9 (n=0). However, there was no statistically significant difference (p>0.05) in the distribution of X-shaped rugae between the age groups regardless of sex (Table VI).

Regarding the distribution of angled palatal rugae in terms of the unification between age groups, it was observed that the highest number of divergent rugae was found in the age group of 12 (n=29) and the lowest number in the age

group of 8 (n=18), while the highest number of convergent rugae was found in the age group of 8 (n=6) and the lowest number in the age group of 7 (n=1). However, there was no statistically significant difference in the distribution of angled palatal rugae in terms of unification between the age groups regardless of sex (p>0.05) (Table VII).

Regarding the distribution of angled palatal rugae according to sex in terms of unification; both divergent (girls=68, boys=73) and convergent (girls=8, boys=13) rugae were found more frequently in boys than in girls. However, when the unifications of the angled palatal rugae were compared independently of age groups, there was no statistically significant difference between the girls and boys (p>0.05) (Table VIII).

**Table VII.** Distribution of angled palatal rugae in terms of unification according to age groups

Unification	Age groups						Statistics
	5-6 years	7 years	8 years	9 years	12 years	13 years	
<b>Divergent</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	25 (89.3)	22 (95.7)	18 (75.0)	26 (83.9)	29 (87.9)	21 (91.3)	-
Mean±SD	0.83±0.79	0.73±0.91	0.60±0.81	0.87±0.82	0.97±1.00	0.70±0.84	0.627
<b>Convergent</b>							<b>p<sup>†</sup></b>
<b>n (%)</b>	3 (10.7)	1 (4.3)	6 (25.0)	5 (16.1)	4 (12.1)	2 (8.7)	-
Mean±SD	0.10±0.31	0.03±0.18	0.20±0.48	0.17±0.46	0.13±0.35	0.07±0.25	0.562

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, <sup>†</sup>Kruskal-Wallis test, results were considered statistically significant for p<0.05.

**Table VIII.** Distribution of angled palatal rugae according to gender in terms of unification

Unification	Girls		Boys		Statistics
	n (%)	Mean±SD	n (%)	Mean±SD	p <sup>†‡</sup>
Divergent	68 (89.5)	0.76±0.89	73 (84.9)	0.81±0.83	0.531
Convergent	8 (10.5)	0.09±0.32	13 (15.1)	0.14±0.38	0.232

n: number of rugae, %: proportion of total number of rugae, SD: standard deviation, <sup>†</sup>Mann-Whitney U test, <sup>‡</sup>results were considered statistically significant for p<0.025 according to Bonferroni correction, <sup>§</sup>results were considered statistically significant for p<0.05.

## Discussion

Palatal rugae are considered defining elements in human identification as they exhibit technical and biological properties such as uniqueness, immutability, longevity, categorizability and practicality (17-19). Indeed, scientific studies evaluating rugae morphology emphasize that palatal rugae are unique to individuals and that morphological differences exist between populations (19-21). However, there is still no consensus on whether palatal rugae morphology changes with age (21,22). Furthermore, no research has been found in the dental literature evaluating the distribution of palatal rugae in Turkish children. Therefore, this study aimed to evaluate palatal rugae characteristics according to age and sex in children.

The existence of many different classifications of palatal rugae morphology, along with disagreements regarding them, shows that there is a need for universal standards. In addition, the subjective nature of identifying similarities and differences between different types of palatal rugae confuses researchers and leads to contradictory interpretations (22,23). For these reasons, a simple and reliable classification system should be used wherever possible in palatine rugae research (24,25).

Previous studies which evaluated differences in rugae morphology across different populations found that classifications based on rugae shape and length were preferred (22,26,27). In the present study, the classification system used was favored due to its practicality, ease of application, and lack of requirement for complicated instrumentation. In this classification system, rugae shapes are categorized into four forms: wavy, curved, straight, and circular (21,24,26). However, in addition to these shapes, angled and fused (X-shaped) shapes were also observed in this study. It should be noted that a modified classification was used in the present study, incorporating angled and fused (X-shaped) forms in addition to the conventional categories (16,22,24). In the current study, plaster models of the patients were scanned using an extraoral scanning device, and then measurement software was employed to

analyze the number, position, shape, length, and unification of palatal rugae on these digital models. This approach aimed to determine the properties of the palatal rugae in digital models, while also preventing the subjectivity of the researcher and the negative effects of abrasions which may occur on the plaster models and be reflected in the results of this study.

This study was designed using predefined age groups based on dentition stages and pubertal growth patterns in order to minimize developmental variability in palatal rugae measurements. The 5-6-year group represented the late primary/early mixed dentition period; the 7-, 8-, and 9-year groups represented the early mixed dentition period; and the 12- and 13-year groups represented the late mixed/early permanent dentition and post-pubertal period. The 10-11-year age range was excluded because it represents a transitional period associated with accelerated maxillary growth, increased interindividual variability, and a higher likelihood of orthodontic treatment initiation, all of which could affect group homogeneity. Children younger than 5 years were also excluded due to rapid craniofacial growth, greater measurement variability, limited cooperation, and reduced standardization of imaging and measurement procedures.

Direct intraoral scanning in pediatric patients may be associated with variability in data quality because of movement- and saliva-related artefacts. Therefore, extraoral indirect scanning was preferred in order to provide standardized acquisition conditions and improve repeatability. In addition, rugae characteristics were recorded in a standardized format using the Integrated Rugoscopy Chart (16). All evaluations were performed by the same investigator, and intra-investigator reliability was assessed using Cohen's Kappa test.

In the present study, the number and distribution of rugae in the right and left halves of the palate were initially evaluated. Comparisons between the genders revealed that the number of rugae was higher in girls, though this difference was not statistically significant, as was observed

in previous studies (25,28). Regarding the distribution of rugae in the right and left halves of the palate, a higher number of rugae were observed in the left half of the palate in girls and in the right half of the palate in boys, though this difference was not statistically significant. In an 8- to 11-year-old Indian population, more palatal rugae were reported in the left half of the palate in girls and in the right half in boys; this result aligned with our findings (28). Conversely, when examining the change in the number of palatal rugae with increasing age, it was observed that 7-year-olds had the highest number of rugae and 13-year-olds had the lowest. However, no statistically significant difference was found between the age groups in terms of the number of palatal rugae. It was noted that the mean number of rugae tended to decrease slightly with increasing age. This finding was consistent with that of Kamala et al. (29). However, there is no consensus in the dental literature regarding changes in the number of palatal rugae with increasing age. According to Lysell (30), the number of rugae remained constant until the age of 23, after which it decreased, whereas Hauser et al. (31) emphasized that the number of rugae continued to increase until the age of 35-40 years. Additionally, the analyses conducted in this study compared the total number of rugae in boys and girls within each age group; however, no statistically significant difference was observed.

The positional characteristics of palatal rugae were also evaluated. In the present study, rugae were most frequently located in positions D, E, and C, whereas no rugae were detected in positions A or B. Venegas et al. (32) reported a different positional pattern, with most rugae located in position E, followed by D, and a small number in positions A and B; this discrepancy may be related to differences in age and population characteristics. No statistically significant sex-related differences were found in rugae position. With respect to age, positions C and E did not differ significantly across groups, whereas rugae in position D showed a significant decrease in some older age groups. This finding may reflect a positional difference across some age groups; however, given the cross-sectional design, it should be interpreted cautiously.

Primary rugae were the predominant length category in the present study. No statistically significant differences in rugae length were observed across age groups or between sexes, in agreement with Thabitha et al. (28). Although a slight age-related decrease in primary rugae was observed, this pattern differed from the findings of Kamala et al. (29) and Kapali et al. (26). These discrepancies may be related

to racial or individual variations. This study also determined that the most common shape of the palatal rugae was wavy and the least common was fused (X-shaped). The wavy shape was followed by curved, angled and straight shapes, respectively, with circular shapes being the least common. Gadicherla et al. (34) reported that the wavy and curved shapes are common in Indian individuals aged 4-16 years, while the circular shape is the least common (33). Similarly, Rajan et al. (25) found that the most common shape was wavy in individuals aged 5-15 years. Examining the distribution of palatal rugae according to gender in terms of shape revealed that curved, wavy, and circular shapes were more prevalent in girls, while angled, straight, and fused (X-shaped) shapes were more prevalent in boys. However, when the shapes of the palatal rugae were compared across the age groups, no statistically significant difference was found between the boys and girls. Pakshir et al. (33) reported that wavy, fused (X-shaped) and straight shapes were more prevalent in girls, while curved and angled shapes were more prevalent in boys among Iranian children aged 6-12. Conversely, Gadicherla et al. (34) emphasized that curved, angled, and circular shapes were more prevalent in girls and that wavy and straight shapes were more prevalent in boys among Indian children. Based on these findings, it was generally accepted that wavy and curved configurations were the most common shapes of palatal rugae based on the results of various studies conducted in different populations (21,35). These differences may reflect population-specific morphological variation, although their practical value for demographic estimation remains uncertain.

In the analysis of the unification of angled palatal rugae, the highest number of divergent rugae were observed in the 12-year-old age group, and the fewest were observed in the 8-year-old age group. Convergent rugae were mostly found in the eight-year-old group and least frequently in the seven-year-old group. However, there was no statistically significant difference in the unification of angled palatal rugae between the age groups, regardless of gender. Kamala et al. (29) also found no correlation between the unification of angled rugae and age. Examining the distribution of the unifications of angled rugae revealed no statistically significant difference between the boys and girls, regardless of the age group. Pakshir et al. (33) reported that both divergent and convergent rugae were more prevalent in boys within the Iranian population. In contrast, Kamala et al. (29) found that both types of rugae were more prevalent in girls within the Indian population. Interestingly, Gadicherla et al. (34) emphasized that girls had more divergent rugae and boys had more convergent rugae. These findings suggest

that unification patterns may vary across populations, but their usefulness for sex estimation remains uncertain.

Comparisons have also been made between twins and between family members in the dental literature (36-40). Taneva et al. (38) reported a correlation between rugae lengths and shapes in female monozygotic twins. All rugae were found to be the same shape in both twins, except for the second rugae on the left side. The authors reported that rugae lengths reflected nearly identical values for both twins. Taneva et al. (38) stated in their case report study that they formed baseline data for a larger-scale study which could be used to compare monozygotic and dizygotic twins and their future siblings. In a study analyzing palatal rugae conducted in India, although differences in rugae shape and length were reported between five dizygotic twins, two twins were found to have some similar forms (41). This finding is consistent with studies suggesting the uniqueness of palatal rugae and the questionable role of genetic factors in determining rugae patterns in twins (41). Another study comparing tooth size, dental arch length and palatal rugae morphology among twins showed that rugae patterns were similar, but not identical (42). One of the 12-year-old male patients included in the present study was a monozygotic twin. When the palatal rugae of these twins were compared, it was seen that the shapes of the first and second rugae on the right and left sides of the palate were the same. However, the remaining rugae were found to differ from each other in terms of both shape and length. In line with these findings, it was concluded that rugae morphology in twin siblings is not identical, but shows sufficient similarity to be useful for individual human identification.

Differences between the present findings and those of previous studies may be explained by several factors. First, genetic background may influence the morphological characteristics of palatal rugae, which could contribute to population-specific variations. Second, environmental influences such as craniofacial growth pattern, oral habits, and local functional factors may affect the development or apparent morphology of rugae during childhood. Third, methodological differences across studies should also be considered. Variations in age range, ethnic composition, sample selection, classification systems, recording techniques, and analysis methods may all influence the reported findings. In particular, differences between direct intraoral assessment, plaster cast evaluation, and

digital model analysis may reduce comparability across studies. Therefore, discrepancies in the literature should be interpreted cautiously and not attributed to a single factor alone.

### **Study Limitations**

It is important to acknowledge the limitations of this study. The sample was restricted to a single population of Turkish children, which may limit the generalizability of the findings to other ethnic or geographic groups. Also, although the age groups were selected to represent specific dentition stages, the exclusion of the 10-11-year age group and children under the age of five may have reduced the ability to capture transitional changes in rugae morphology. In addition, the digital data were obtained from plaster models derived from conventional impressions and digitized using an extraoral scanner rather than through direct intraoral scanning. Although this approach provided standardized acquisition conditions, the lack of direct intraoral scanning should be considered an important methodological limitation. In addition, only one type of extraoral scanner was used, and results may vary with different scanning technologies. Although the study compared predefined age groups, its cross-sectional design does not permit definitive conclusions regarding longitudinal developmental changes in palatal rugae over time. Finally, this study did not evaluate intra-population variation related to environmental or genetic factors beyond age and sex, which could have influenced the stability and morphology of palatal rugae.

It is recommended that future studies explore larger and more diverse populations across a range of ethnic backgrounds in order to enhance the external validity of their findings. The reproducibility of rugae assessment across platforms may be determined by conducting comparative studies which employ a variety of scanning technologies and direct intraoral scanning methods. Longitudinal studies which track the same individuals over time could provide deeper insights into developmental changes in palatal rugae and their forensic reliability. Furthermore, the integration of digital palatal rugae analysis with other biometric markers, such as dental arch form or craniofacial characteristics, has the potential to enhance its application in forensic identification, particularly in pediatric populations.

## Conclusion

Within the limitations of this cross-sectional study, the palatal rugae characteristics in Turkish children aged 5-13 years showed no statistically significant differences according to age or sex in terms of number, position, length, shape, or unification. These findings suggest that palatal rugae may have limited utility for age estimation in this population when used alone. Further longitudinal and multi-population studies are needed in order to better clarify their potential role in forensic applications.

## Ethics

**Ethics Committee Approval:** Ethical approval for the present study was provided by the Clinical Research Ethics Committee of Ankara University Faculty of Dentistry (approval number: 6/8, date: 21.03.2018).

**Informed Consent:** Written informed consent was obtained from the parents or legal guardians of all participants, and assent was obtained from the children whenever appropriate.

## Footnotes

### Authorship Contributions

Surgical and Medical Practices: B.B.S., A.D., K.O., Concept: B.B.S., L.Ö., A.D., Design: B.B.S., L.Ö., A.D., Data Collection or Processing: B.B.S., A.D., K.O., Analysis or Interpretation: B.B.S., L.Ö., K.O., Literature Search: B.B.S., A.D., Writing: B.B.S., L.Ö., A.D., K.O.

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