ORIGINAL RESEARCH

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Correlation between fingerprint pattern and palatal rugae forms.

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Abstract
Introduction. The patterns formed during the development of our organism hide deeper connections than initially thought. Fingerprints and palatal rugae have a common embryonic origin, they are strictly genetically coded, which reflects the connection between craniofacial development and external phenotypic traits. **Aim of the study.** The main purpose of this study was to examine the correlations between fingerprint types and the morphology of palatal rugae. To achieve this, we analysed the gender distribution of these developmental markers and the impact of orthodontic treatment on them, evaluating the co-occurrence and clinical variations of different patterns. **Material and Methods.** A total of 63 volunteers participated in the research. The analysis of palatal rugae was performed on study models, evaluating the shape, continuity, direction, and length of the rugae. For fingerprint examination, an ink pad and the rolled fingerprint method were used. We classified the fingerprints into arch, loop, and whorl categories. For the calculation we used standard statistical tests, the validity was verified within the medically accepted 5% margin of error ($p < 0.05$). **Results.** The most frequent fingerprint was the loop-type (47.61%). The longest average rugae was showed in the Arch-type fingerprint group (8.90 mm). Males had greater average rugae length (8.83 mm), the orthodontically treated group showed on average the shortest rugae (8.66 mm). A statistical trend was noted in the gender distribution, regarding the direction of the rugae ($p = 0.045$; one-tailed test). Although we observed morphological differences in terms of gender and orthodontic treatment, no statistically significant difference was shown in the Kruskal–Wallis test for the investigated parameters. **Conclusions.** The research highlights the individual variability of developmental markers. It validates the differences between genders and the uniqueness of palatal rugae. The relationship between fingerprints and palatal rugae can provide important data to support a better understanding and further research of craniofacial and palatal development.

Keywords: palatal rugae, fingerprints, dermatoglyphics, orthodontics, craniofacial development, gender dimorphism.

Introduction

Beyond the fact that identifying people is a scientific need, it is a fundamental part of how we connect as a society. When we think of identification, the first thing that comes to our mind are fingerprints, but recently more and more research has focused on alternative markers. Palatal rugae is one of them. They are incredibly useful in clinical dentistry because they offer a reliable, easy-to-access way to analyse morphology [1, 2]. Both palatal rugae and dermatoglyphics are determined genetically and remain permanent throughout life, serving as essential and constant biometric indicators.
Their uniqueness is so pronounced that even monozygotic twins show micro-structural differences in their palatal and digital patterns [3, 4].

Looking at their embryological development, these structures form during the same intrauterine period, between the 12th and 14th weeks of gestation. They both share a common superficial ectodermal origin [5]. Palatal rugae originate from the mesenchyme of the first branchial arch, fingerprint configuration appears at the limb buds, influenced by both genetic factors and mechanical forces within the amniotic fluid [6].
Basic identification is no longer the primary concern in studying palatal rugae morphology. In fact, these structures can point directly to specific dentomaxillary variations, like dental agenesis. Research shows it links directly to certain rugae shapes, which strongly suggests that they share regulatory growth factors during development [7]. Dermatoglyphic patterns are undergoing similar investigations to determine if they could be markers for hereditary conditions established during foetal life [8, 9]. Because they develop at the same time, it makes sense to study digital fingerprints and palatal rugae together. Finding a direct correlation between them could significantly

advance both forensic science and craniofacial skeletal analysis [10, 11].

The aim of the present study was to further investigate these potential correlations. To better understand craniofacial phenotypic variations and their relevance to clinical dentistry, this study evaluates these developmental markers between genders and their relationship with orthodontic status.

Material and methods

This research was designed as a cross-sectional observational study. The study received formal approval from the Ethics Committee of George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Târgu Mureș, approval number 4052/04.03.2026. All participants signed an informed consent form. A total of 63 volunteers (21 males, 42 females) aged 18–58 years (mean age: 24.65) were selected using convenience sampling. Out of the total sample, 26 participants (41.26%) had a history of orthodontic treatment. The remaining 37 participants (58.73%) had never received this type of therapy.

Patients with previous dental expansion were not excluded from the study, because these orthodontic procedures only expand the dental arch. They do not modify the skeletal base, so the palatal mucosa remains unaffected. Patients who had worn any type of skeletal expander were initially excluded from the study.

To keep all personal data strictly confidential, every participant received a unique numeric code. This simple step made it possible to accurately match their fingerprints to the correct maxillary models later in the study.

Fingerprints were collected using the traditional ink transfer method. Before the registration, participants cleaned and dried their digits to eliminate sebum. To record the complete pattern, we used rolled "nail-to-nail" impressions, using a black ink pad. We scanned all the prints using an HP Color LaserJet device (HP Inc., Palo Alto, CA, USA). Converting them to digital made the analysis much easier, magnification allowed a more detailed examination. We categorized them as arches, loops, or whorls based on the criteria established by Santhosh [5].

For the documentation of the palate, we took maxillary impressions; to guarantee the fidelity we followed standardized clinical protocols. Impressions were taken using Kromopan® alginate (Lascod S.p.A., Sesto Fiorentino, Italy). Models were cast on the same day using Gipsodent® Class III dental stone (S.C. Tehnodent P.C. S.R.L., Bucharest, Romania). The linear length of primary rugae was measured on study models using a high-precision digital calliper (MyProject, OWIM GmbH & Co. KG, Germany; Accuracy: ±0.03 mm). The palatal rugae were delineated with a 6H graphite pencil for clear visualization.

The rugae were classified by length into primary (5–10 mm), secondary (3–4 mm), and fragmentary (< 3 mm) followed by the criteria applied by Armstrong et al. [7]. We focused exclusively on the primary rugae. This evaluation included the analysis of the (1) shape: straight: a line with no bends or curves; curved: slightly bent; wavy: presents a serpentine appearance or a small curvature at one end; circular: forms a continuous and well-defined ring. The (2) continuity: convergent: start separately from the midline and join toward the lateral area; divergent: have a common origin on the midline and branch outward; distinct: individual rugae, without points of union, classified strictly by their shape. The (3) direction: type I: Postero-Anterior - the origin is located posterior to the termination); type II: Perpendicular - the origin and termination are in the same transverse plane); type III: Antero-Posterior - the origin is located anterior to the termination; type IV: Multidirectional, rugae with variable orientation that do not fit into the mentioned patterns.

In the data processing, we chose to analyse the configuration of the palatal rugae by grouping them into specific combinations. We explicitly chose not to split the data between the right and left sides. This decision was made to simplify the statistical analysis and focus on the general typology of everyone.

To run the statistics, we assigned a numerical code to each pattern and grouped them into specific combinations (Tables 1-3).

Results

Statistical Analysis

Data were centralized and organized using Microsoft Excel® (Microsoft Corp., Redmond, WA, USA). The analysis started with basic descriptive statistics, including frequencies, means, and extreme values for each variable. The Kolmogorov–Smirnov (K-S) test revealed that the distribution was non-normal, so we chose non-parametric methods for the comparisons. To explore the link between fingerprints and palatal rugae, the study population (n=63) was categorized by fingerprint pattern into three groups: arches, loops, and whorls. Then we applied the Kruskal–Wallis test to analyse whether rugae morphology, including shape, continuity, and direction, varied between these three categories. Next the data was filtered to compare rugae characteristics (length, shape, direction, and continuity) based on gender and orthodontic status (history of orthodontic treatment versus no treatment). We used the Mann–Whitney U test for these two-group comparisons. For all statistical procedures, the significance level was set at $p < 0.05$.

Loops were by far the most common, appearing in 30 people (47.61%). Whorls were found in 20 participants (31.74%), while arches were the least frequent, representing only 13 subjects (20.63%).

In the arch subgroup the most common was curved-curved shape (5 people), distinct-distinct continuity (8 people), and Type I-I direction (8 subjects). In the whorl subgroup dominance of curved-curved shape (6 subjects), distinct-distinct continuity (12 subjects), and Type I-I direction (15 participants) was observed. In the Loop subgroup a predominance of straight-curved shape (8 participants), distinct-distinct continuity (16 subject), and Type I-I direction (24 subjects) was registered.

Regarding the length of the palatal rugae, the largest values were identified in subjects with Arch fingerprints (mean 8.90 mm). The smallest values were in the whorl group (mean 8.77 mm).

The Kruskal–Wallis test showed no statistically significant differences ($p > 0.05$) in palatal rugae morphology (shape, continuity, and direction) across the different fingerprint types. (Tabel 4.)

Comparison by gender

In both males and females, the most frequent value for continuity was distinct-distinct, while for direction, the most common pattern was I-I (posterior-anterior-posterior-anterior).

Our results showed that rugae shapes vary significantly between the sexes. The straight-straight pattern predominated in the majority of female subjects, while the curved-curved shape was the more prevalent finding in males. The Loop was the dominant fingerprint type across the entire sample.

Measurements also revealed that palatal rugae are generally longer in males (mean: 8.83 mm) than in females (mean: 8.60 mm).

After analysing the data, we used the Mann-Whitney U test to see if there were any statistical differences between males and females. For shape, continuity and fingerprint type, we found no significant differences ($p > 0.05$). The only notable observation was in the direction of the palatal rugae, here, we obtained a $p = 0.045$ in the one-tailed analysis, indicating a statistical trend. Even though the result of 0.091 (two-tailed) is not strictly significant, our data show that direction is the feature where men and women differ the most in our group [12] (Table 6).

Comparison by orthodontic treatment

When comparing participants based on their orthodontic history, they present the same dominant characteristics. The most frequent fingerprint type was Loops, the most common continuity at the palatal rugae was distinct-distinct, and the direction was also identical: posterior-anterior- posterior-anterior. A difference between groups was observed in rugae shape, among those who underwent treatment the curved-curved shape was the most frequent, whereas in those who did not receive treatment, the curved-sinuous shape prevailed.

Those who had braces had shorter rugae on average (8.66 mm) compared to those who did not (8.90 mm) (Table 7).

The Mann-Whitney U test showed no significant differences between the treated and untreated groups for any of the main parameters. Based on these p-values, there is

no evidence in our sample to suggest that orthodontic treatment has any impact on these anatomical markers [13] (Table 8).

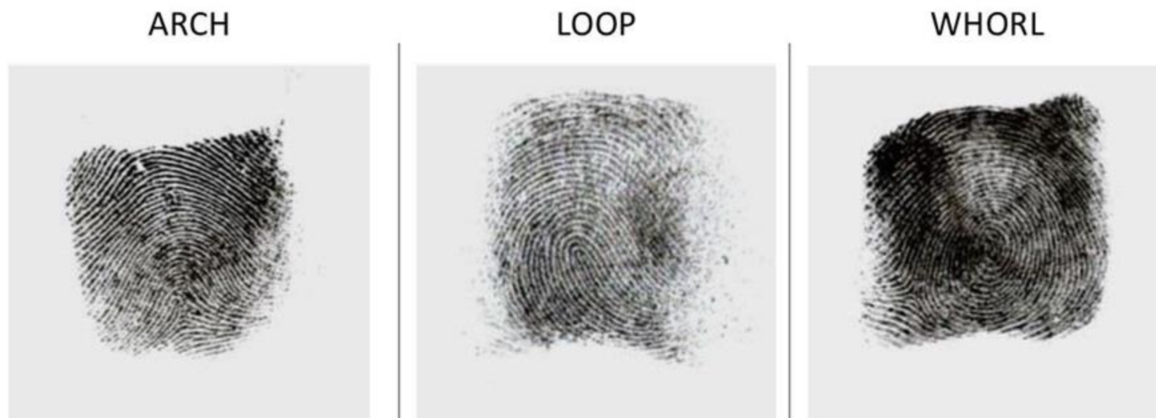

Figure 1. – Fingerprints shape identification (personal collection)

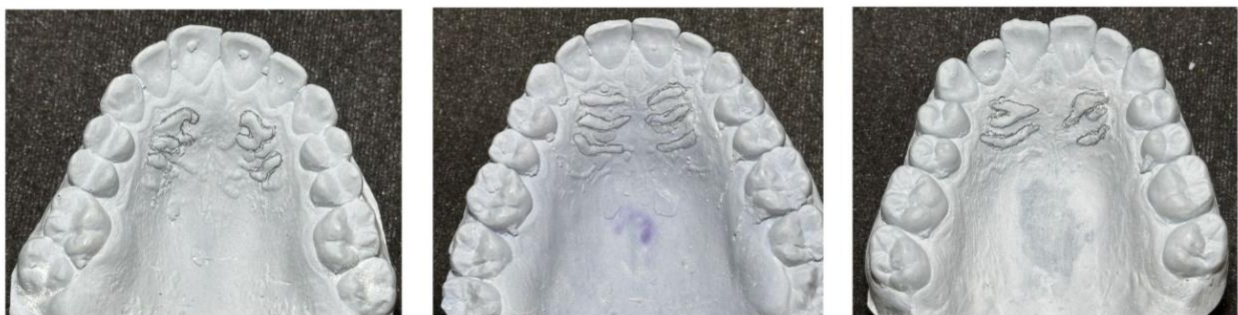

Figure 2. – Rugae identification on maxillary casts (personal collection)

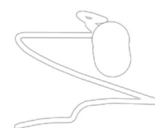

Table 1. Combinations for palatal rugae shapes.

Code	Description	Abbreviation
1.	straight-straight	ST-ST
2.	curved-curved	CU-CU
3.	sinuous-sinuous	S-S
4.	circular-circular	CI-CI
5.	straight-curved	ST-CU
6.	straight-sinuous	ST-S
7.	straight-circular	ST-CI
8.	curved-sinuous	CU-S
9.	curved-circular	CU-CI
10.	sinuous-circular	S-CI
11.	incomplete determination	NO

Table 2. Combinations for palatal rugae continuity.

Code	Description	Abbreviation
1.	convergent-convergent	C-C
2.	divergent-divergent	D-D
3.	convergent-divergent	C-D
4.	distinct-distinct	DIS-DIS
5.	distinct-convergent	DIS-C
6.	distinct-divergent	DIS-D

Table 3. Combinations for palatal rugae direction.

Code	Combination
1.	I–I
2.	I–II
3.	I–III
4.	I–IV
5.	II–II
6.	II–III
7.	II–IV
8.	III–III
9.	III–IV
10.	IV–IV

Table 4. Statistical analysis of the data

Morphological Parameter	N	Kruskal–Wallis (H)	df	p-value	Significance
Shape	63	0.0556	2	0.973	Not Significant (NS)
Continuity	63	0.3604	2	0.835	Not Significant (NS)
Direction	63	2.0810	2	0.353	Not Significant (NS)

Table 5. Rugae length comparison between genders

Pattern Type	Side	Mean (mm)	Minimum (mm)	Maximum (mm)
Male	Right	8.70	7.34	11.33
	Left	8.96	6.27	13.73
	Combined Average	8.83	6.80	12.53
Female	Right	8.62	5.33	11.25
	Left	8.58	5.78	10.86
	Combined Average	8.60	5.55	11.05

Table 6. Analysis of the rugae length, shape, continuity, and fingerprint type between genders

Morphological Parameter	Mann-Whitney U	Z-score	p-value (one-tailed)	p-value (two-tailed)
Shape	389.5	-0.751	0.226	0.453
Continuity	437.5	-0.051	0.48	0.959
Direction	325	-1.691	0.045	0.091
Fingerprint Type	347	-1.371	0.085	0.171

Table 7. Comparison of rugae length between the orthodontically treated and untreated group

Pattern Type	Side	Mean (mm)	Minimum (mm)	Maximum (mm)
With orthodontic treatment	Right	8.61	6.60	10.10
	Left	8.72	5.78	10.86
	Combined Average	8.66	6.19	10.48
Without orthodontic treatment	Right	8.86	5.33	11.33
	Left	8.93	6.22	13.73
	Combined Average	8.90	5.77	12.53

Table 8. Statistical analysis of rugae morphology between orthodontically treated and untreated group

Morphological Parameter	Mann-Whitney U	Z-score	p-value (one-tailed)	p-value (two-tailed)
Shape	442.5	-0.537	0.295	0.591
Continuity	454.5	-0.37	0.356	0.711
Direction	478	-0.042	0.483	0.967
Fingerprint	476	-0.07	0.472	0.944

Discussions

The main goal of this study was to explore how palatal rugae morphology and fingerprint patterns relate to one another. The consistency we found in the fingerprint types across our group suggests that we had a solid, balanced sample to work with for this biometric analysis. The most common fingerprint pattern in our sample were loops (47.61%), followed by whorls (31.74%), and arches (20.63%). This distribution mirrors the global data, where loops are generally the dominant pattern, making about 60-65% of the general population [14].

One noticeable observation was the link between rugae length and fingerprint complexity. We found that individuals with 'arch' patterns actually had the longest rugae, averaging 8.96 mm. In contrast, those with more complex fingerprints, loops or whorls showed slightly shorter measurements. While the difference was not massive, it is notable that the longest rugae recorded in our study (13.73 mm) belonged to a participant in the arch category. We also detected some slight asymmetry, the right side dominated in the arch group, whereas the left side showed higher values for those with loops and whorls. This kind of individual variation really highlights how unique everyone is.

While there is clearly a link between these two structures, the fact that there is not a strict "mathematical" rule connecting them suggests that their genetic control is quite complex. Their formation is guided by "reaction-diffusion" as a turing model mechanisms [7], which act as the basic biological instructions. However, the fine details are shaped by epigenetic and biomechanical factors in utero, such as the mechanical stress and pressure of the amniotic fluid on the volar pads [15], and the developmental movements of the tongue during palatal shelf elevation [16]. Each of our 63 participants showed a unique biological identity, a result of both genetic coding and specific prenatal development.

A central finding in our study was the presence of sexual dimorphism. We found a notable statistical trend in the direction of the rugae between men and women. While the two-tailed analysis stayed just above the significance level, a one-tailed test indicated a directional correlation ($p = 0.045$). This suggests that men generally exhibit larger rugae and distinct morphological patterns compared to women, which supports the potential use of these markers in sex identification [12].

In the context of orthodontic treatment, shorter rugae (8.66 mm) were found in treated patients. The results suggest this has more to do with the patients' original dental morphology, like a narrow upper arch, than any changes caused by the treatment. The fact that rugae remain stable even during orthodontic movement only reinforces their value as a reliable biometric tool. Unlike teeth, which can change position or be lost, palatal rugae act as a permanent "genetic archive" [13].

Our findings suggest that the correlation between fingerprints and palatal rugae presents a unique opportunity for early screening of dento-maxillary anomalies. Because both structures develop at the same time in the embryo, they indicate fundamental genetic patterns. Pinpointing specific combinations of these patterns could provide a simple, non-invasive way to monitor children in pediatric dentistry, ultimately making orthodontic interventions much more efficient.

From a practical standpoint, integrating digital intraoral scanning with Artificial Intelligence (AI) algorithms can automate analysis. This eliminates the subjectivity of manual measurements, and it would move toward a more standardized, high-precision diagnostic model [17, 18].

The main limitation of our study is the lack of preliminary power calculation, which would have been useful to determine whether the number of subjects in the treated and untreated groups was sufficient to detect a clinically relevant difference, even if the sampling was based on convenience sampling. Our current study was an exploratory, pilot, cross-sectional observational study in which the number of eligible participants was limited for practical reasons, and therefore we did not perform a formal a priori power calculation. Our results should be interpreted with caution, especially when comparing treated and untreated subgroups. Future studies should work with larger sample sizes and use a preliminary

sample size estimate to ensure adequate statistical power. Creating extensive digital databases will deepen our understanding of these early developmental trends. These digital tools could transform rugoscopy from a traditional forensic instrument into a highly reliable and objective component of predictive dentistry.

However, we must be cautious with these interpretations. It is difficult to create a perfect predictive model because the way the face and mouth develop is not only about genetics. A variety of factors form this process, like inherited traits, environmental factors, and local conditions during growth. Therefore, our results should be seen as interesting early observations rather than final rules. To truly understand these biological links, future studies will need to look at much larger groups of people to better explain the high level of individual variety we saw in our research.

Conclusions

The study confirms that palatal rugae are stable and unique, making them a reliable biometric marker. Essentially, they function as a permanent "genetic archive" that remains unchanged throughout a person's life. Our findings suggest that fingerprint complexity may be inversely related to the linear development of palatal rugae, indicating a synchronized yet complex genetic control during embryonic development.

The identification of sexual dimorphism trends and specific bilateral asymmetry highlights the potential of rugoscopy in anthropological and clinical screening. While environmental factors play a significant role in craniofacial growth, the correlation between dermatoglyphics and rugae morphology offers a promising, non-invasive way for further research in predictive dental medicine. These early insights provide a strong basis for future large-scale studies. They are a necessary first step in creating objective screening tools to detect the need for orthodontic care in children as early as possible.

Author Contributions (CRediT Taxonomy)

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Conflict of interest

None to declare.

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Policy on the Use of Artificial Intelligence (AI) Tools

Generative AI Statement:

During the preparation of this work the author(s) used ChatGPT in order to improve English language and structure Reference style. After using this ChatGPT, the author(s) reviewed and edited the content as needed and are fully responsible for the originality and integrity of the content of the manuscript.

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