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ORIGINAL ARTICLE

Reliability and Accuracy of Palatal Rugoscopy as a tool for Gender Identification in Orthodontic Patients

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ABSTRACT

Background: Palatal rugoscopy is a reliable forensic tool for human identification due to the uniqueness and stability of palatal rugae. However, orthodontic treatment especially involving palatal appliances may alter rugae morphology, potentially affecting its accuracy in gender identification. This study aimed to evaluate the reliability and diagnostic accuracy of palatal rugoscopy for sex determination in orthodontic patients.

Methods: A cross-sectional analytical study was conducted on 360 participants divided into three groups: non-orthodontic controls, orthodontic patients without palatal appliances, and those treated with palatal appliances. Rugae patterns were assessed using Lysell and Thomas & van Wyk classifications. Statistical analysis included ANOVA, chi-square test, ROC analysis, and logistic regression.

Results: Significant sexual dimorphism was observed in controls, with higher rugae counts in females ($p < 0.05$). Diagnostic accuracy was highest in controls (86.7%, AUC = 0.91), reduced in orthodontic patients without appliances (74.2%), and lowest in those with palatal appliances (61.7%) ($p < 0.001$). Palatal appliances significantly reduced rugae count and increased asymmetry, affecting sex prediction.

Conclusions: Orthodontic treatment, particularly with palatal appliances, compromises the reliability of rugoscopy for gender identification. Caution is advised when applying this method in forensic cases involving orthodontically treated individuals.

KEYWORDS:

• Palatal Rugoscopy • Gender Identification • Orthodontic Treatment • Forensic Odontology • Palatal Rugae

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INTRODUCTION

Forensic odontology encompasses a broad spectrum of identification techniques, among which palatal rugoscopy has garnered increasing scientific interest as a reliable, non-invasive adjunct tool for personal identification.[1] Palatal rugae are irregular, asymmetric fibromucous ridges located on the anterior third of the hard palate, lateral to the incisive papilla.[2] Their unique morphological configuration encompassing number, length, shape, and directional orientation is considered individually distinct, bilaterally asymmetric, and remarkably stable throughout an individual's lifetime.[3] Owing to their protected anatomical position, rugae demonstrate exceptional resistance to thermal injury, mechanical trauma, and postmortem decomposition, making them particularly valuable in forensic scenarios where conventional identification modalities such as fingerprinting and DNA profiling are compromised or unavailable.[4] Furthermore, the consistent and unique patterns of these rugae make them suitable as stable reference points for superimposing three-dimensional virtual models in orthodontic assessments, enhancing their utility beyond forensic applications.[5]

Numerous studies have investigated the utility of rugae patterns in personal identification, with several reporting statistically significant sexual dimorphism in rugae morphology between biological males and females. Parameters such as total rugae number, predominant shape classification, and directional orientation have demonstrated gender-discriminating potential across diverse ethnic and geographic populations.[6] However, a critical and largely unaddressed gap exists in the current literature virtually all reference datasets and sex estimation norms for rugoscopy have been established using non-orthodontic or dentally untreated populations. Orthodontic treatment, particularly involving palatal appliances such as transpalatal arches, Nance buttons, and removable retainers, exerts direct mechanical forces on the palatal mucosa and underlying hard palate, potentially displacing, distorting, or altering rugae morphology in ways that could undermine the forensic applicability of existing classification norms.[7]

Given that orthodontic treatment prevalence continues to rise globally, a substantial proportion of individuals presenting for forensic identification may carry rugae patterns modified by prior dental intervention.[8] It is therefore imperative to critically evaluate whether standard rugoscopy-based gender identification retains its reliability and accuracy in orthodontically treated patients. The present study aims to address this lacuna by systematically comparing rugae morphology and sex identification accuracy across orthodontic and non-orthodontic populations using both conventional and digital analytical methods.

MATERIAL AND METHODS

Study Design

This was a cross-sectional analytical observational study designed to evaluate the reliability and accuracy of palatal rugae morphology as a gender identification tool specifically within an orthodontic patient population a group in whom rugae patterns may be mechanically altered by palatal appliance therapy, rendering standard rugoscopy-based sex estimation norms potentially inapplicable. The study compared rugae characteristics between male and female orthodontic patients across two subgroups: those who had undergone fixed orthodontic treatment without palatal appliances, and those who had received treatment involving palatal expanders or transpalatal arches. A third group of age and sex-matched non-orthodontic individuals served as controls.

Study Setting

The study was conducted in the Department of Orthodontics at Geetanjali Dental College and Research Centre, Udaipur. Pre-treatment and post-treatment orthodontic study casts routinely archived in the orthodontic records department constituted the primary data source for the orthodontic subgroups. Control group impressions were recorded prospectively from patients attending the orthodontic department. Institutional ethics committee approval and informed consent from all participants or guardians were mandatory prior to data collection.

Sample Size Estimation

Sample size was computed using G*Power 3.1 for independent samples comparison of proportions, based on an expected correct

sex identification rate of 75% in orthodontic patients versus 88% in controls (derived from prior rugoscopy literature), with α = 0.05 and power = 0.80. This yielded a minimum of 52 individuals per sex per subgroup. With three subgroups and two sexes each, the total minimum enrollment was 312 participants. Accounting for 15% exclusion due to poor cast quality or incomplete records, the target sample was 360 participants — 60 males and 60 females in each of the three groups.

Inclusion and Exclusion Criteria

Inclusion criteria: Individuals aged 15–35 years with full permanent dentition excluding third molars; for orthodontic subgroups, confirmed completed fixed orthodontic treatment with well-documented pre-and post-treatment plaster or digital study casts; biological sex confirmed from hospital records; casts of adequate quality with all rugae clearly reproducible without voids or tears. Controls must have no history of any orthodontic treatment, removable or fixed.

Exclusion criteria: Individuals with cleft palate, submucous cleft, or surgical palatal repair; presence of palatal tori, fibroma, ulceration, or any mucosal pathology distorting rugae; history of rapid palatal expansion (RPE) with documented midpalatal suture opening, as this represents a fundamentally different mechanical intervention; systemic connective tissue disorders; transgender individuals or those on cross-sex hormonal therapy (as biological sex-rugae correlations may not apply); poor quality, fractured, or dimensionally inaccurate casts; and individuals who have undergone orthognathic surgery involving the maxilla.

Methodology for Analyzing Data

Maxillary impressions for control and prospective orthodontic participants were recorded using polyvinylsiloxane (PVS) impression material and poured in Type IV dental stone. Archival orthodontic casts were digitized using calibrated images (resolution 1024×1024 pixels) to generate .jpeg files, ensuring uniform digital analysis irrespective of cast age or storage condition. All physical casts were also analyzed directly under ×2 magnification loupes under standardized cool-white illumination.

Rugae assessment employed two validated classification systems in parallel: the Lysell (1955) system for length categorization (primary >5 mm, secondary 3–5 mm, fragmentary <3 mm) and the Thomas & van Wyk (1988) system for shape (straight, curved, wavy, circular, convergent, divergent) and directional orientation (anterior, posterior, transverse). For each participant, total rugae number, unification pattern, and bilateral asymmetry index was recorded. Two trained examiners blinded to participant sex and group independently scored all casts; an ICC ≥ 0.85 was required before main analysis. A third examiner arbitrated discordant scores.

Outcome Data

Primary outcomes were: (a) correct sex identification rate (%) using rugoscopy alone in each of the three groups and (b) rugae dimorphism index values across groups and sexes. Secondary outcomes included identification of which specific rugae parameters shape, number, length category, or directionality best discriminate between males and females within the orthodontic population; the effect of palatal appliance type on rugae displacement magnitude; and bilateral asymmetry differences between sexes and treatment groups.

Statistical Analysis

Normality of continuous variables was assessed by the Shapiro–Wilk test. Descriptive statistics (mean ± SD or median with IQR) were reported for all rugae parameters across sex and group. Between-group and between-sex comparisons of rugae parameters were performed using two-way ANOVA (factors: sex × group) with Tukey's post-hoc correction, or the Kruskal–Wallis test with Dunn's correction for non-normal data. Correct sex identification rates were compared across the three groups using the chi-square test or Fisher's exact test. Diagnostic accuracy of rugoscopy as a sex identification tool within each group was expressed as sensitivity, specificity, positive predictive value, and area under the ROC curve (AUC). Pre-to-post-treatment rugae changes in orthodontic subgroups were analyzed using paired t-tests or Wilcoxon signed-rank tests. Binary logistic regression was used to identify which rugae parameters independently predict biological sex within the orthodontic population after

controlling for group. Inter and intra-examiner agreement was reported as ICC for continuous measures and Cohen's weighted kappa for categorical classifications. All analyses were conducted in SPSS v26 and R v4.3, with $p < 0.05$ as the threshold for statistical significance.

RESULTS

The study enrolled 360 participants (60 males and 60 females in each of the three groups). Table 1 confirms that age distribution was comparable across groups and sexes (mean age 24.4 ± 5.2 years; $p > 0.05$ for all comparisons), ensuring that subsequent differences in rugae morphology are not confounded by age. Analysis of rugae parameters (Table 2) revealed significant sexual dimorphism in the control group: females exhibited higher total rugae count (9.1 vs. 8.2, $p = 0.01$), more primary rugae (5.2 vs. 4.5, $p = 0.02$), and a greater number of curved and circular rugae compared to males. Orthodontic treatment without palatal appliances caused minor, nonsignificant reductions in these parameters, whereas the palatal appliance group showed statistically significant decreases in total rugae count (7.8 vs. 7.3 in males), primary rugae, and curved rugae, along with increased bilateral asymmetry ($p < 0.001$ for group effect). These findings indicate that palatal appliances mechanically distort rugae, attenuating sexspecific features.

Table 1: Baseline demographic characteristics of the study population

Group	Sex	N (n=360)	Mean age (years) ± SD	Age range (years)	p-value*
Control (non-orthodontic)	Male	60	24.3 ± 5.2	16–34	0.78
	Female	60	24.7 ± 5.5	15–35	
Ortho without palatal appliance	Male	60	23.9 ± 4.9	17–34	0.65
	Female	60	24.1 ± 5.1	16–35	
Ortho with palatal appliance (expander/TPA)	Male	60	24.5 ± 5.3	15–35	0.71
	Female	60	24.8 ± 5.0	16–34	

*Independent t-test for age differences across groups and sexes (no significant difference, ensuring comparability).

Table 2: Comparison of rugae morphological parameters across groups and sexes

Parameter (mean ± SD)	Control (non-orthodontic)		Ortho without palatal appliance		Ortho with palatal appliance		Two-way ANOVA *p-values		
	Male (n=60)	Female (n=60)	Male (n=60)	Female (n=60)	Male (n=60)	Female (n=60)	Sex	Group	Interaction
Total rugae count	8.2 ± 1.4	9.1 ± 1.5	7.9 ± 1.6	8.8 ± 1.4	7.3 ± 1.7	7.8 ± 1.6	0.01*	0.003*	0.52
Primary rugae (>5 mm)	4.5 ± 1.1	5.2 ± 1.2	4.1 ± 1.3	4.9 ± 1.1	3.4 ± 1.2	3.9 ± 1.3	0.02*	<0.001*	0.41
Curved rugae	3.1 ± 0.9	3.8 ± 1.0	2.9 ± 1.0	3.5 ± 0.9	2.5 ± 1.1	2.9 ± 1.0	0.01*	0.008*	0.67
Circular rugae	0.8 ± 0.5	1.2 ± 0.6	0.7 ± 0.5	1.0 ± 0.5	0.4 ± 0.4	0.6 ± 0.5	0.02*	0.001*	0.88
Bilateral asymmetry index	0.18 ± 0.06	0.16 ± 0.05	0.22 ± 0.08	0.20 ± 0.07	0.31 ± 0.10	0.28 ± 0.09	0.09	<0.001*	0.34

*P<0.05 significant

The diagnostic accuracy of rugoscopy (Table 3) was highest in controls (correct identification rate 86.7%, AUC = 0.91). Accuracy dropped to 74.2% in orthodontic patients without palatal appliances and further declined to 61.7% in those treated with palatal expanders or transpalatal arches ($\chi^2 = 18.3$, $p < 0.001$). This progressive reduction directly reflects the loss of sexually dimorphic rugae traits following orthodontic mechanotherapy.

Table 3: Diagnostic accuracy of rugoscopy for sex identification in each group

Group	Correct identification rate (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (95% CI)
Control (non-orthodontic)	86.7 (104/120)	85.0	88.3	87.9	85.5	0.91 (0.86–0.96)
Ortho without palatal appliance	74.2 (89/120)	73.3	75.0	74.6	73.8	0.79 (0.72–0.86)
Ortho with palatal appliance	61.7 (74/120)	60.0	63.3	62.1	61.3	0.65 (0.56–0.74)
Overall	74.2 (267/360)	72.8	75.6	74.9	73.5	0.78 (0.74–0.82)

Chi-square test across groups: $\chi^2 = 18.3$, $p < 0.001$. Pairwise comparisons: Control vs. Ortho without palatal: $p = 0.02$; Control vs. Ortho with palatal: $p < 0.001$; Ortho without vs. with palatal: $p = 0.03$.

Binary logistic regression (Table 4) identified lower total rugae count (OR = 0.66 per unit increase, p = 0.001), fewer primary rugae (OR = 0.70, p = 0.01), fewer curved rugae (OR = 0.68, p = 0.008), and higher asymmetry (OR = 1.34, p = 0.009) as independent predictors of male sex. Belonging to the palatal appliance group also independently predicted male sex (OR = 1.68, p = 0.03), likely because applianceinduced distortion mimics maletype rugae patterns. Collectively, these results demonstrate that palatal orthodontic appliances significantly compromise the reliability of rugoscopy for sex estimation, necessitating caution or alternative methods when using posttreatment dental casts in forensic identification.

Table 4: Binary logistic regression independent predictors of male sex

Predictor variable	β coefficient	SE	Adjusted OR	95% CI	p-value
Total rugae count	−0.42	0.12	0.66	0.52–0.83	0.001*
Primary rugae count	−0.35	0.14	0.70	0.53–0.93	0.01*
Curved rugae count	−0.38	0.15	0.68	0.51–0.91	0.008*
Bilateral asymmetry index	0.29	0.11	1.34	1.08–1.66	0.009*
Group (reference: Control)					
Ortho without palatal appliance	0.18	0.23	1.20	0.76–1.89	0.43
Ortho with palatal appliance	0.52	0.24	1.68	1.05–2.69	0.03*
Age	0.02	0.03	1.02	0.96–1.08	0.51

DISCUSSION

The present study's findings align with and extend the existing body of evidence on palatal rugae in forensic odontology, while introducing novel data on the impact of orthodontic mechanotherapy. Our observation of significant sexual dimorphism in rugae parameters (Table 2), including higher total and primary rugae counts in females, is consistent with the systematic review and meta-analysis,[9,10] which reported grouped sensitivity and specificity rates of 89% and 83% for rugoscopy. However, that review also cautioned against the use of rugoscopy as a standalone tool due to high heterogeneity across studies. The high diagnostic accuracy in our control group (AUC = 0.91; Table 3) supports the discriminant power of rugoscopy, but this accuracy declined significantly with orthodontic intervention, underscoring the influence of treatment-related variables.[11] Specifically, while some studies suggest that palatal rugae generally maintain their stability post-orthodontic treatment.[8]

Our study's key finding is the differential effect of orthodontic treatment on rugae morphology. While the subgroup treated without palatal appliances showed non-significant changes, those treated with palatal expanders or transpalatal arches exhibited significant reductions in total and primary rugae counts and increased bilateral asymmetry (Table 2). These results corroborate those of Makrygiannakis *et al*.[12], who found that palatal rugae change shape during orthodontic treatment, with extraction treatment exerting a more pronounced effect. Furthermore, Tey *et al*.[13], in a scoping review, reported that palatal expansion techniques, especially rapid maxillary expansion, can modify rugae morphology. The substantial decrease in correct sex identification rates from 86.7% in controls to 61.7% in the palatal appliance group (Table 3) provides quantitative evidence of this effect.

Our logistic regression analysis (Table 5) identified total rugae count, primary rugae count, curved rugae count, and asymmetry index as independent predictors of sex, with palatal appliance group membership emerging as a significant independent predictor of male sex (OR = 1.68, p = 0.03). This finding suggests that orthodontic expansion may produce rugae patterns that mimic male-type morphology, potentially due to stretching of palatal mucosa.[14] similarly reported that orthodontic treatment induces various morphometric changes in palatal rugae patterns that may complicate human identification.[15]

Finally, the excellent inter and intra-examiner reliability (ICC ≥ 0.79) demonstrates that standardized classification systems can yield reproducible results, which is essential

for forensic applications.[16] However, given the demonstrated effect of orthodontic appliances on rugae morphology, caution is warranted when using post-treatment dental casts for sex estimation in forensic identification. Future studies should explore whether these changes are reversible or persist long-term, and whether specific rugae parameters are more resistant to orthodontic forces than others.

CONCLUSION

The present study demonstrates that while palatal rugoscopy remains a valuable and non-invasive adjunct for gender identification, its reliability is significantly influenced by orthodontic interventions. Clear sexual dimorphism in rugae morphology was evident in non-orthodontic individuals, supporting its forensic applicability under normal conditions. However, orthodontic treatment particularly involving palatal appliances such as expanders and transpalatal arches induces measurable alterations in rugae patterns, including reduced rugae count, diminished characteristic shapes, and increased asymmetry. These changes lead to a substantial decline in diagnostic accuracy, thereby limiting the use of rugoscopy as a standalone tool in orthodontically treated populations. Clinicians and forensic experts must therefore exercise caution when interpreting post-treatment casts. It is recommended that rugoscopy be used in conjunction with other identification methods such as DNA analysis or dental records to enhance accuracy, especially in cases involving prior orthodontic therapy.

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REFERENCES

1. Kumar T: Role of palatal rugoscopy to establish sexual dimorphism as an adjunct in personal identification: A forensic study. J Forensic Dent Sci. 2023, 84–96. 10.18311/jfds/13/2/2021.17
2. Paliwal A, Wanjari S, Parwani R: Palatal rugoscopy: Establishing identity. J Forensic Dent Sci. 2010, 2:27–31. 10.4103/0974-2948.71054
3. Ata-Ali J, Ata-Ali F: Forensic dentistry in human identification: A review of the literature. J Clin Exp Dent. 2014, 6:e162-7. 10.4317/jced.51387.
4. Smitha T, Vaswani V, Deepak V, Sheethal HS, Hema KN, Jain VK: Reliability of palatal rugae patterns in individual identification. J Oral Maxillofac Pathol. 2021, 25:555. 10.4103/jomfp.jomfp_269_21.
5. Roselli L, Mele F, Suriano C, Santoro V, Catanesi R, Petruzzi M: Palatal rugae assessment using plaster model and dental scan: a cross-sectional comparative analysis. Front Oral Health. 2024, 5:1456377. 10.3389/froh.2024.1456377.
6. Gautam N, Patil SG, Krishna RG, Agastya H, Mushtaq L, Kumar KV: Association of palatal rugae pattern in gender identification: An exploratory study. J Contemp Dent Pract. 2017, 18:470–3. 10.5005/jp-journals-10024-2067.
7. Bavaresco D, Von Meusel LDZ, Franco A, Makeeva I, Paranhos LR, Cericato GO: Morphology of the palatal rugae before and after orthodontic treatment with and without rapid maxillary expansion and dental extractions. Indian J Dent Res. 2020, 31:241–6. 10.4103/ijdr.IJDR_12_19.
8. Hashim A, Mascarenhas R, Umar D, Amin V, Shetty S, Bavikara Maniyankod S: Stability of palatal rugae post-orthodontics: implications for forensic identification and clinical superimposition. Egypt J Forensic Sci. 2025, 15:. 10.1186/s41935-025-00483-9.
9. Andrade RNM, Vieira WA, Bernardino ÍM, Franco A, Paranhos LR. Reliability of palatal rugoscopy for sexual dimorphism in forensic dentistry: A systematic literature review and meta-analysis. Arch Oral Biol. 2019 Jan;97:25-34. doi: 10.1016/j.archoralbio.2018.10.009.
10. Lavanya R, Boringi M, Alluri K, Sujatha M. Palatal Rugae in Gender Discrimination: Auxiliary or Hindrance? A Systematic Review. J Res Dent Maxillofac Sci. 2022; 7(4):260-266.
11. Kapoor P, Ragini, Kaur H (2015) Rugoscopy: A Diagnostic Appurtenance for Malocclusion or just a Forensic Aid? - A Pilot Study. J Forensic Res 6: 272. doi: 10.4172/2157-7145.1000272.
12. Makrygiannakis MA, Konstantonis D, Vastardis H, Athanasiou AE, Halazonetis DJ. Palatal rugae change shape following orthodontic treatment: a comparison between extraction and non-extraction borderline cases using fractal analysis and 3D superimposition. Eur J Orthod. 2024 Dec 4;47(1):cjae070. doi: 10.1093/ejo/cjae070.
13. Tey, Sock Nee, et al. "Stability of palatal rugae after orthodontic/orthopaedic expansion: a scoping review." Australasian Orthodontic Journal, vol. 39, no. 1, Australian Society of Orthodontists Inc., 2023, pp. 158-170. https://doi.org/10.2478/aoj-2023-0018.

14. Deepak V, Malgaonkar NI, Shah NK, Nasser AS, Dagrus K, Bassle T. Palatal rugae patterns in orthodontically treated cases, are they a reliable forensic marker? J Int Oral Health. 2014 Sep;6(5):89-95.

15. Ali B, Shaikh A, Fida M. Stability of Palatal Rugae as a Forensic Marker in Orthodontically Treated Cases. J Forensic Sci. 2016 Sep;61(5):1351-5. doi: 10.1111/1556-4029.13129.

16. Shukla D, Chowdhry A, Bablani D, Jain P, Thapar R. Establishing the reliability of palatal rugae pattern in individual identification (following orthodontic treatment). J Forensic Odontostomatol. 2011 Jul 1;29(1):20-9.