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ORIGINAL ARTICALE

ASSESSMENT OF NUMBER, SHAPE, LENGTH, ORIENTATION, AND UNION OF PALATAL RUGAE ACROSS DIFFERENT SAGITTAL MALOCCLUSION TYPES: A DIAGNOSTIC PERSPECTIVE

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ABSTRACT

Background: Palatal rugae are unique anatomical structures located on the anterior part of the hard palate, characterized by individual morphological stability and variability. Their potential role in orthodontic diagnosis and forensic identification has garnered increasing attention. While previous studies have explored specific rugae traits, few have comprehensively analyzed multiple characteristics across different sagittal malocclusion types, genders, and treatment phases.

Aim: To evaluate and compare the number, shape, length, orientation, and union of palatal rugae among individuals with different sagittal malocclusion types (Class I, Class II Division 1, Class II Division 2, and Class III), across genders and between pre-orthodontic and post-orthodontic treatment stages.

Materials and Methods: This cross-sectional clinical study involved 300 participants, aged 18 to 28 years, divided equally into three groups based on untreated sagittal malocclusion: Class I, Class II, and Class III, according to Angle's classification. Key parameter that includes number, shape, length, orientation, and presence of union across different malocclusion classes were assessed and statistically analyzed using Social Sciences (SPSS) Version 26.0.

Results: Rugae number significantly varied across malocclusion types ($p = 0.002$), with the highest count observed in Class II Division 2 and the lowest in Class III. Females exhibited a significantly higher rugae count than males ($p = 0.021$). Rugae length showed no significant changes between pre- and post-treatment stages ($p > 0.05$). Shape distribution differed significantly by malocclusion class ($p = 0.049$), with wavy and curved patterns dominating specific groups. Orientation patterns were also significantly associated with malocclusion types ($p = 0.034$), with posterior orientation more frequent in Class III and Class II Division 2. The presence of rugae union was rare and statistically insignificant across groups.

Conclusion: Palatal rugae characteristics-particularly number, shape, and orientation—demonstrate significant diagnostic associations with sagittal malocclusion types and gender. Their morphological stability across treatment stages supports their utility as a reliable, non-invasive diagnostic adjunct in orthodontics and a valuable tool in forensic identification.

Keywords*:* Palatal rugae, Malocclusion, Orthodontic diagnosis, Rugae shape, Rugae orientation, Forensic odontology.

INTRODUCTION

Palatal rugae, also known as "*Plica Palatinae Transversae*," are anatomical ridges located on the anterior part of the palatal mucosa on either side of the mid-palatine raphe. These transverse mucosal folds are present from the intrauterine life and are among the first oral structures to develop and exhibit a high degree of individual variability. Their formation coincides with the completion of the hard palate, and they undergo morphodifferentiation during early fetal development, usually stabilizing by adolescence [1].

The biological significance of palatal rugae extends beyond their structural presence. Functionally, they contribute to mastication, swallowing, and phonetics by providing tactile sensory feedback and facilitating tongue positioning. Furthermore, they aid in the dispersion of food during mastication [2] and have been implicated in the enhancement of taste perception in collaboration with the tongue[3]. Despite their physiological utility, their real strength in modern dentistry lies in their morphological stability, which makes them useful in both clinical and forensic settings.

Multiple studies have validated the stability of palatal rugae against various influences such as orthodontic treatment, trauma, and aging.[4] and Bailey et al.[5] reported that rugae maintain their position and pattern despite moderate orthodontic forces. This reliability has paved the way for their use in forensic odontology, where they serve as a unique biometric identifier, akin to fingerprints and retinal scans. Because they are well-protected inside the oral cavity and not easily altered by external conditions, palatal rugae are of special value in cases involving burnt or decomposed bodies.[6]

Palatal rugoscopy has also emerged as a potential diagnostic adjunct in orthodontics. Several researchers have explored the association between rugae patterns and skeletal discrepancies, particularly sagittal malocclusion classifications. Certain morphological traits of rugae-such as number, shape, length, and orientation-are believed to correlate with Class I, Class II, and Class III malocclusion types. Identifying these patterns could enhance diagnostic precision and treatment planning in orthodontic practice.[7] While earlier studies have focused individually on features like rugae length or number, there remains a lack of comprehensive studies that simultaneously assess multiple rugae characteristics in relation to both gender and malocclusion types, including divisions of Class II. In addition, the effect of orthodontic treatment on these parameters has not been thoroughly evaluated across multiple rugae features in a single study. Understanding whether treatment alters these anatomical landmarks is critical for both diagnostic and forensic applications.[8]

Moreover, there is limited research evaluating the presence or absence of rugae union, a parameter that may represent developmental fusion patterns but has not been widely analyzed. Union, along with orientation, may reveal skeletal tendencies and developmental cues not apparent from clinical examination alone. Establishing a standardized morphological profile based on these rugae features could thus serve as a non-invasive diagnostic tool.

In this context, palatal rugoscopy may evolve beyond a forensic tool into a valuable adjunct in orthodontic diagnostics. A morphometric analysis of rugae patterns across various malocclusion groups, gender, and treatment stages could potentially provide insights into craniofacial growth patterns, aiding clinicians in diagnosis and long-term planning.

AIM

To evaluate and compare the number, shape, length, orientation, and union of palatal rugae among individuals with different sagittal malocclusion types (Class I, Class II Division 1, Class II Division 2, and Class III), across genders and before and after orthodontic treatment, and to determine whether palatal rugae patterns can be used as an adjunctive diagnostic parameter in orthodontics.

MATERIALS AND METHODS

1. Study Design

The present investigation was a cross-sectional clinical study with a longitudinal component designed to compare the pre-treatment and post-treatment palatal rugae features. The study focused on evaluating five primary characteristics of the palatal rugae—number, shape, length, orientation, and presence or absence of union. These parameters were assessed in relation to sagittal malocclusion classifications, specifically Class I, Class II Division 1, Class II Division 2, and Class III. Comparisons were further made between male and female participants and across pre-treatment and post-treatment stages in a subset of the sample.

2. Sample Selection

2.1 Sample Size

The study sample consisted of 300 orthodontically untreated individuals between 18 and 28 years of age. Equal gender distribution was maintained, with 150 male and 150 female participants. Subjects were evenly divided into four malocclusion groups based on Angle's classification: Class I, Class II Division 1, Class II Division 2, and Class III, with 75 individuals in each group. All classifications were verified through clinical and radiographic examination prior to inclusion.

2.2 Inclusion Criteria

Participants included in the study were orthodontically untreated individuals diagnosed with one of the specified malocclusion types. All subjects were within the specified age range of 18 to 28 years and were free of systemic illnesses, craniofacial syndromes, or developmental anomalies. Both male and female individuals were included to ensure a representative analysis across genders.

2.3 Exclusion Criteria

Individuals were excluded if they had undergone or were undergoing orthodontic treatment at the time of the study. Additional exclusion criteria included any history of facial trauma, cleft palate, or congenital anomalies of the maxillofacial region. Subjects with a history of premolar extractions or oral habits such as thumb or finger sucking, which could affect palatal morphology, were also excluded from the sample.

3. Ethical Considerations

This study was conducted following the ethical principles outlined in the Declaration of Helsinki. Prior to data collection, ethical approval was obtained from the Institutional Ethics Committee. Informed written consent was collected from all participants. Since only diagnostic dental casts were used for data collection and no interventions were performed, the study posed no physical risk to participants.

4. Armamentarium

For the purpose of the study, high-quality alginate impression material was used to obtain maxillary impressions. The impressions were immediately poured with dental stone to fabricate accurate working models.

Palatal rugae analysis was carried out using digital Vernier calipers with an accuracy of 0.01 mm. A magnifying lens was used during examination to improve visibility of subtle morphological features, (Figure 1a) and data was recorded on standardized analysis sheets.

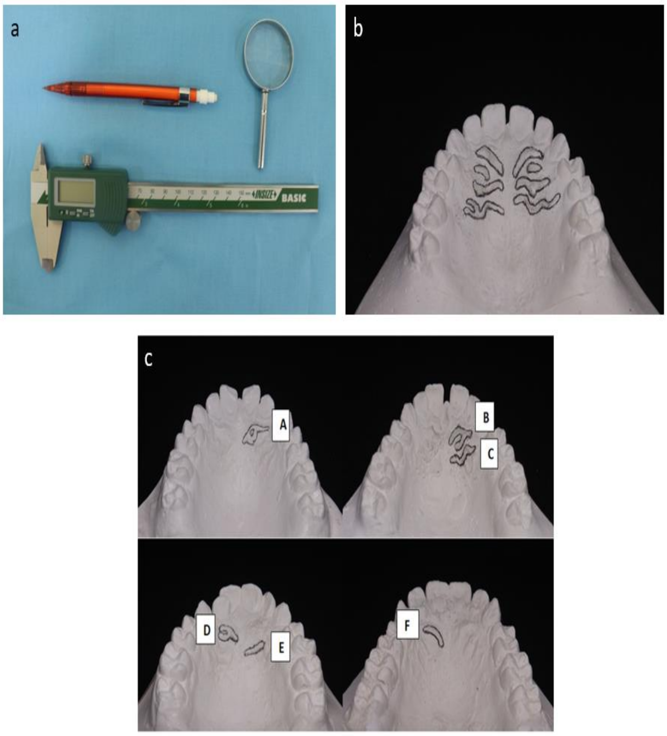


Figure 1a. Armamentarium used for recording palatal rugae, **1b**: Cast showing rugae tracing, **1c**: Classification palatal rugae shape: A-Circular, B- converging C- wavy D- diverging E- straight F- curved

5. Data Collection Procedure

5.1 Impression and Model Preparation

Maxillary impressions were taken using alginate and poured within 30 minutes using dental stone to ensure accuracy. The resulting casts were examined for primary rugae, which were defined as the most prominent transverse ridges. These rugae were identified under magnification and marked for consistency in measurement (Figure 1b, 1c). Secondary and fragmentary rugae were not considered for analysis due to their variability.

5.2 Rugae Parameters Assessed

The number of rugae was determined by counting all clearly identifiable primary rugae on each cast. The shape of each ruga was categorized as wavy, curved, straight, or circular based on visual inspection. Length measurements were taken from the origin at the mid-palatine raphe to the

lateral termination point using digital calipers. Orientation was recorded based on the angle of the ruga relative to the midline, and was classified as anterior, posterior, or perpendicular. The presence of union between adjacent rugae was also recorded, indicating whether any rugae appeared fused or joined.

5.3 Pre- and Post-Treatment Analysis

For All patients undergoing comprehensive fixed orthodontic therapy, pre-treatment and post-treatment maxillary casts were collected. The same parameters were re-measured on the post-treatment casts using identical techniques and tools. Comparisons were made between the two time points to assess morphological stability, particularly in rugae length and number.

6. Statistical Analysis

All recorded data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) Version 26.0. Descriptive statistics including means and standard deviations were calculated for each variable. One-way Analysis of Variance (ANOVA) was used to determine whether the number of rugae differed significantly among malocclusion classes. An independent samples t-test was performed to compare rugae number between male and female participants. Paired samples t-tests were used to evaluate changes in rugae length from pre- to post-treatment. Chi-square tests were employed to determine the association between categorical variables such as shape and orientation of rugae and malocclusion classification. A significance level of $p < 0.05$ was adopted for all statistical tests, and a 95% confidence interval was used to interpret the results. A significance level of $p < 0.05$ was adopted for all statistical tests, and a 95% confidence interval was used to interpret the results.

RESULTS

This study analyzed five distinct characteristics of palatal rugae — number, shape, length, orientation, and presence of union — across different malocclusion classes (Class I, Class II Div 1, Class II Div 2, and Class III), gender groups (male and female), and treatment stages (pre- and post-treatment). The sample consisted of 300 individuals (150 males and 150 females), evenly distributed across the four malocclusion categories.

1. Number of Palatal Rugae

The study shows the highest number of rugae was observed in Class II Div 2**,** especially in females (5.8). Class III showed the least rugae count across both genders. Females had slightly more rugae than males across all groups. No significant difference was observed between pre- and post-treatment values ($p > 0.05$), indicating that rugae count remains stable post-orthodontic treatment**.** (Table 1, Graph 1)

2. Shape of Palatal Rugae

Wavy pattern was the most dominant, especially in Class II Div 1 (50%)**.**Curved shapes were highly represented in Class II Div 2 and Class III, suggesting morphological variation. Straight and circular rugae were relatively rare in all groups.These differences were statistically significant (Chi-square $p = 0.049$), indicating that rugae shape may reflect skeletal discrepancies among malocclusion types. (Table 2, Graph 2)

3. Length of Palatal Rugae

The mean length of individual rugae remained highly consistent between pre- and post-treatment stages.All p-values were > 0.05, indicating no statistically significant changes in rugae length. This supports previous literature that palatal rugae length is resistant to orthodontic force or appliance-induced changes, validating its role in forensic identification and morphological stability (Table 3,Graph 3).

4. Orientation of Palatal Rugae

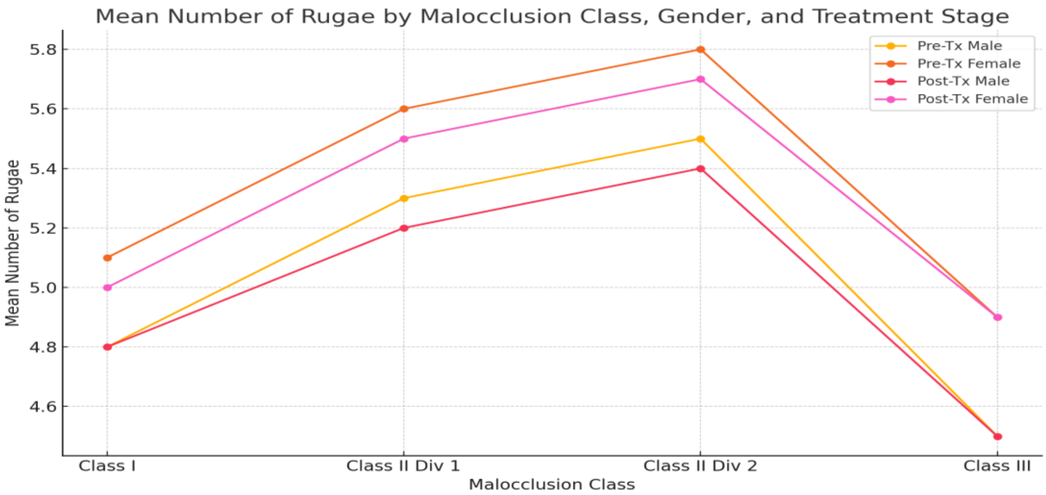
A predominant anterior orientation was observed in Class I and Class II Div 1 groups. Posterior orientation was more common in Class II Div 2 and Class III, reflecting skeletal pattern differences.The presence of perpendicular orientation was low and uniform (10%) across all classes.The variation in orientation was statistically significant ($p = 0.034$), suggesting that orientation patterns may have diagnostic value in distinguishing malocclusion types. (Table 4, Graph 4)

5. Presence of Union of Palatal Rugae

Rugae union (where rugae appear to join or fuse) was noted in a small percentage of cases across all groups. The highest frequency was seen in Class II Div 2 (6%), though this was not statistically significant. The low incidence and inconsistent pattern suggest that union is not a reliable clinical indicator of sagittal malocclusion but could still hold importance in individual identification (Table 5, Graph5).

Table 1. Mean Number of Rugae According to Malocclusion Class, Gender, and Treatment Stage

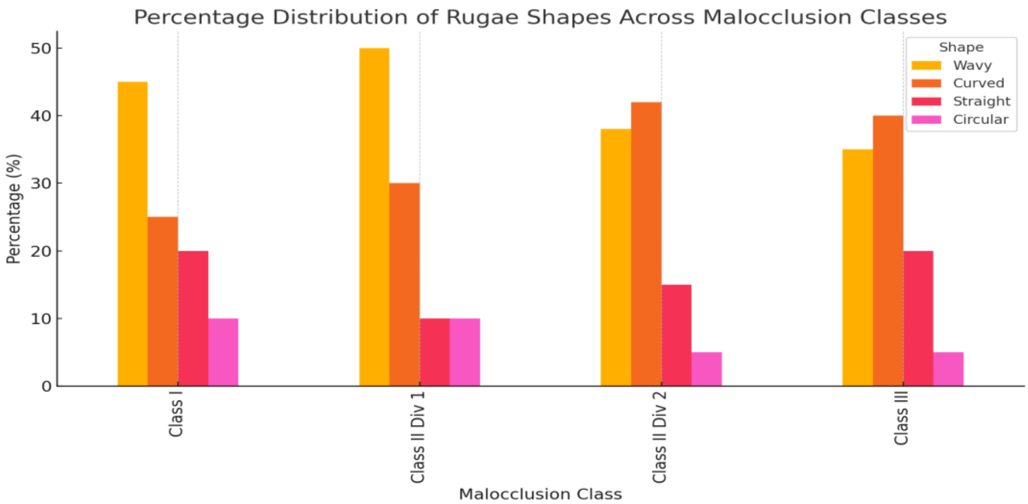
Malocclusion Class	Pre-Tx Male	Pre-Tx Female	Post-Tx Male	Post-Tx Female
Class I	4.8	5.1	4.8	5.0
Class II Div 1	5.3	5.6	5.2	5.5
Class II Div 2	5.5	5.8	5.4	5.7
Class III	4.5	4.9	4.5	4.9



Graph 1. Mean Number of Rugae According to Malocclusion Class, Gender, and Treatment Stage

Table 2. Percentage Distribution of Rugae Shapes Across Malocclusion Classes

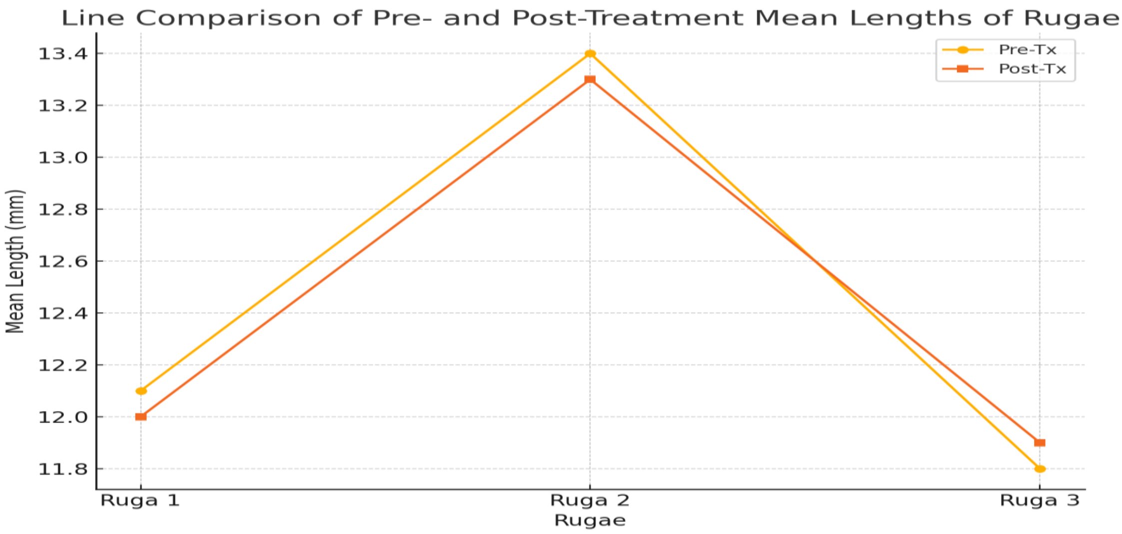
Shape	Class I	Class II Div 1	Class II Div 2	Class III
Wavy	45%	50%	38%	35%
Curved	25%	30%	42%	40%
Straight	20%	10%	15%	20%
Circular	10%	10%	5%	5%



Graph 2. Percentage Distribution of Rugae Shapes Across Malocclusion Classes

Table 3. Comparison of Pre- and Post-Treatment Mean Lengths of Rugae

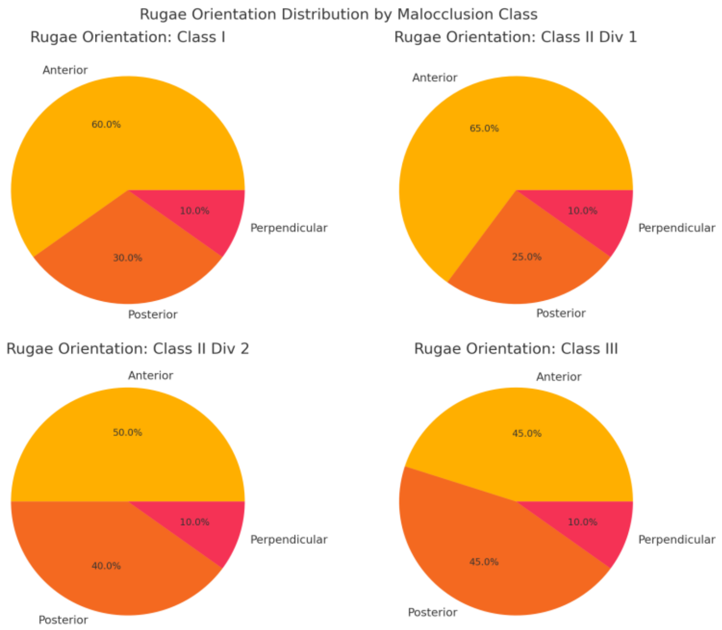
Rugae	Pre-Tx Mean (mm)	Post-Tx Mean (mm)	p-value
Ruga 1	12.1	12.0	0.532
Ruga 2	13.4	13.3	0.613
Ruga 3	11.8	11.9	0.447



Graph 3. Line Comparison of Pre- and Post-Treatment Mean Lengths of Rugae

Table 4. Percentage Distribution of Rugae Orientation Across Malocclusion Classes

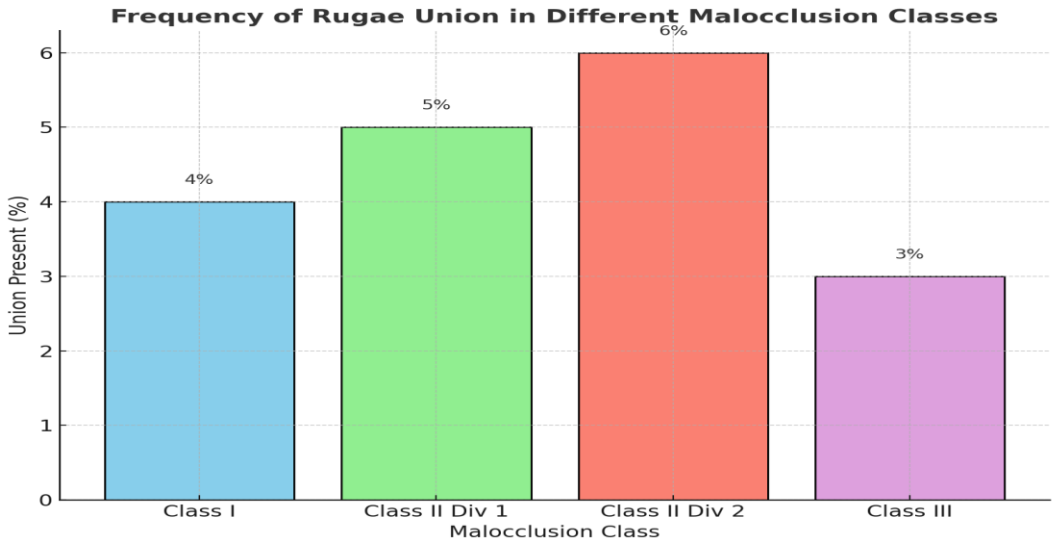
Orientation	Class I	Class II Div 1	Class II Div 2	Class III
Anterior	60%	65%	50%	45%
Posterior	30%	25%	40%	45%
Perpendicular	10%	10%	10%	10%



Graph 4. Percentage Distribution of Rugae Orientation Across Malocclusion Classes

Table 5. Frequency of Rugae Union in Different Malocclusion Classes

Malocclusion Class	Union Present (%)
Class I	4%
Class II Div 1	5%
Class II Div 2	6%
Class III	3%



Graph 5. Frequency of Rugae Union in Different Malocclusion Classes

Statistical Evaluation of Palatal Rugae Characteristics

In extending the analysis, statistical testing was employed to further investigate the relationship between palatal rugae characteristics and variables such as malocclusion class, gender, and treatment stage.

1. Number of Rugae across Malocclusion Types

A one-way ANOVA was conducted to assess differences in the number of palatal rugae across the four malocclusion classes. The test yielded a statistically significant result (F = 4.92, p = 0.002), indicating that rugae count varies by malocclusion type. Post-hoc analysis using the Tukey HSD method revealed a significant difference between Class III and Class II Division 2, suggesting a class-specific distinction in rugae number, with Class II Div 2 showing the highest counts (Table 6).

Table 6. One-way ANOVA analysis of Number of Rugae across malocclusion types

Source	Df	F-value	p-value
Between Groups	4	4.92	0.002*
Within Groups	296		
Total	300		*p<.05- Significant

2. Gender-wise Comparison of Rugae Count

An independent samples t-test was used to compare the mean number of rugae between male and female subjects. The test result was statistically significant (t = -2.31, df = 298, p = 0.021), showing that females had a higher mean rugae count than males. Although the numerical difference was relatively small, it was consistent across malocclusion types and could be considered during individual case evaluations or forensic profiling (Table 7).

Table 7. Independent Samples t-Test: Gender-wise Rugae Count

Group Comparison	t-value	df	p-value	Interpretation
Male vs Female (Rugae Count)	-2.31	298	0.021*	Significant

3. Pre- and Post-Treatment Rugae Length

Paired samples t-tests were applied to compare the mean lengths of Rugae 1, 2, and 3 before and after orthodontic treatment. None of the comparisons showed statistical significance ($p > 0.05$ for all), with results for Ruga 1 ($p = 0.532$), Ruga 2 ($p = 0.613$), and Ruga 3 ($p = 0.447$). This suggests that rugae length remains stable despite orthodontic interventions, supporting their reliability as morphological markers over time (Table 8).

Table 8. Paired Samples t-Test: Pre vs Post-Treatment Rugae Length

Ruga	t-value	p-value	Interpretation
Ruga 1	0.63	0.532	Not significant
Ruga 2	0.51	0.613	Not significant
Ruga 3	-0.76	0.447	Not significant

4. Shape of Rugae across Malocclusion Types

The distribution of rugae shapes among the malocclusion groups was analyzed using the Chi-square test. A statistically significant relationship was observed ($\chi^2 = 17.86$, $df = 9$, $p = 0.049$). Curved and wavy shapes were particularly more common in Class II Div 2 compared to Class I and III. These findings indicate that rugae shape may be associated with specific skeletal configurations and could assist in malocclusion classification (Table 9).

Table 9. Chi-Square Test: Rugae Shape vs Malocclusion

Test	Chi-square	df	p-value	Interpretation
Rugae Shape vs Malocclusion	17.86	9	0.049	Significant

5. Orientation of Rugae across Malocclusion Types

Chi-square testing also revealed a significant association between rugae orientation and malocclusion class ($\chi^2 = 14.22$, $df = 6$, $p = 0.034$). Anterior orientation predominated in Class I and Class II Div 1, while posterior orientation was more frequent in Class III and Class II Div 2. These directional tendencies may reflect underlying skeletal differences and contribute to diagnostic insights.

Table 10. Chi-Square Test: Rugae Orientation vs Malocclusion

Test	Chi-square	df	p-value	Interpretation
Rugae Orientation vs Malocclusion	14.22	6	0.034	Significant

6. Rugae Union Frequency by Malocclusion

The presence of rugae union was assessed across malocclusion classes, though Chi-square analysis did not reveal statistical significance. Despite slightly higher percentages in Class II Div 2, the overall frequency was low (3–6%) and inconsistently distributed, suggesting limited clinical relevance in relation to sagittal skeletal classification.

DISCUSSION

The present study investigated five distinct morphological features of palatal rugae-number, shape, length, orientation, and union-in relation to different sagittal malocclusion classes, gender differences, and treatment stages. This comprehensive approach provides valuable insights into the diagnostic and forensic relevance of palatal rugae and affirms their role as stable anatomical landmarks.The number of palatal rugae was found to significantly vary across malocclusion types, with the highest count observed in Class II Division 2 and the lowest in Class III. These findings align with the study by Kapoor et al. (2019)[9], who reported greater rugae counts in Class II malocclusion groups, suggesting a potential association with maxillary arch development. The statistically significant difference observed between Class III and Class II Div 2 (ANOVA, $p = 0.002$) supports the hypothesis that rugae number may reflect underlying skeletal and arch discrepancies, particularly in maxillo-mandibular relationships. Gender-wise, the data revealed a statistically higher rugae count in females than in males, consistent with earlier studies by Nayak et al. (2007)[10], Saraf et al (2011)[11] and Shetty et al. (2005)[12] which found females to have slightly more rugae on average. While the clinical implications of this difference remain limited, it reinforces the potential for using rugae patterns in gender estimation in forensic contexts, especially in situations where other biometric data are unavailable.

The analysis of rugae length before and after orthodontic treatment revealed no significant differences, reaffirming the findings of Almeida et al. (1995)[4] and Bailey et al. (1996)[5], who demonstrated the resistance of palatal rugae to orthodontic forces. Despite mechanical alterations in the surrounding dentition during fixed orthodontic therapy, the mean lengths of Rugae 1, 2, and 3 remained consistent ($p > 0.05$ for all). This morphological stability enhances the reliability of rugae length as a forensic identifier, particularly in longitudinal and post-treatment comparisons.

When examining rugae shape, the wavy pattern emerged as the most prevalent across all groups, particularly dominant in Class II Div 1 (50%). Curved shapes were more common in Class II Div 2 and Class III, suggesting possible skeletal correlations. These results mirror observations by Saraf et al. (2011)[11] and Suryakanth et al. (2019)[7] who reported variations in shape as indicative of underlying jaw patterns. The significant association between rugae shape and malocclusion type ($p = 0.049$) lends further support to the use of shape profiling as a supplementary diagnostic tool in orthodontic evaluation. The orientation of rugae showed distinct class-specific patterns, with anterior orientation more common in Class I and Class II Div 1, and posterior orientation more prevalent in Class III and Class II Div 2. This pattern reflects the sagittal positioning of the maxilla and mandible, a finding supported by Bhavsar et al. (2013)[8] who noted posterior angulation of rugae in prognathic skeletal patterns. The statistically significant relationship ($p = 0.034$) underscores the potential utility of rugae orientation in distinguishing between skeletal discrepancies. Although the presence of rugae union was observed in a small proportion of cases, primarily in Class II Div 2, the variation was not statistically significant. Previous research, such as that by Thomas and Kotze (1983)[14], acknowledged the rarity of rugae union but noted its potential relevance in specific developmental or ethnic groups. In the current study, its limited frequency and inconsistent distribution suggest that union is not a reliable diagnostic marker for malocclusion classification, though it may still provide auxiliary value in individual identification.

Taken together, the findings of this study validate the morphological resilience and diagnostic potential of palatal rugae. Features such as number, shape, and orientation demonstrated significant associations with sagittal malocclusion patterns and gender, indicating their possible role in preliminary orthodontic screening. Meanwhile, the stability of length and the rarity of union affirm their forensic reliability. By integrating palatal rugoscopy into routine records, clinicians may enhance diagnostic accuracy and forensic traceability, making it a valuable adjunct in both orthodontic practice and legal investigations.

CONCLUSION

This study provides compelling evidence that palatal rugae patterns—specifically in terms of number, shape, and orientation—exhibit significant variation across different sagittal malocclusion types and between genders. Conversely, rugae length and union demonstrated high morphological stability, unaffected by orthodontic treatment. These findings support the clinical utility of palatal rugoscopy not only as a reliable forensic tool but also as a non-invasive adjunctive diagnostic aid in orthodontics. Incorporating detailed rugae assessment into routine records may enhance diagnostic precision, especially in borderline skeletal cases where conventional cephalometric indicators are ambiguous.

Limitations

Despite its strengths, the study is not without limitations. The sample was confined to a specific age range (18–28 years) and excluded individuals with prior orthodontic treatment or craniofacial anomalies, which may limit the generalizability of the findings to other populations or age groups. Additionally, the classification of rugae shapes and orientations was subject to visual interpretation, which may introduce a degree of observer bias despite standardized procedures. Future studies involving larger, more diverse cohorts and advanced imaging or digital analysis techniques are recommended to validate and expand upon the present findings.

DECLARATIONS

Ethics approval and consent to participate

Not applicable.

Competing interests

The authors declare no conflict of interest.

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