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ORIGINAL ARTICLE

Investigating the Association between Palatal Rugae and Sagittal Malocclusion: A Clinical Study

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ABSTRACT

Introduction: Palatal rugae are unique anatomical ridges located on the anterior hard palate, remaining stable throughout an individual's life. In forensic odontology and orthodontics, they serve as key landmarks. The stability of palatal rugae, coupled with their resistance to change, suggests potential diagnostic value, especially in sagittal malocclusion classified as Class I, II, or III by Angle's system. This study investigates the association between palatal rugae patterns and sagittal malocclusion, exploring whether their morphological characteristics can aid in malocclusion diagnosis.

Objectives: To examine whether palatal rugae patterns (length and width) are significantly associated with sagittal malocclusions (Class I, II, and III) and to assess their potential role as non-invasive diagnostic tools for orthodontic assessment.

Methodology: This cross-sectional clinical study involved 300 participants, aged 18 to 28, divided equally into three groups based on untreated sagittal malocclusion: Class I, Class II, and Class III, according to Angle's classification. Strict inclusion

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criteria ensured participants had no history of orthodontic treatment, systemic diseases, facial trauma, or habits affecting palatal anatomy. Pre-treatment maxillary dental models were made using high-quality alginate impressions and dental stone casts, focusing on primary palatal rugae for analysis. Key parameters measured were the mesio-distal (MD) length and anterio-posterior (AP) width of the rugae, with data collected using digital calipers. Statistical analysis was conducted with SPSS Ver 26.0, employing ANOVA to compare rugae dimensions between malocclusion groups, and Pearson Correlation Coefficient to assess the relationship between rugae patterns and malocclusion. A significance level of $p<0.05$ was set.

Results: The paired sample t-test results revealed no statistically significant difference in palatal rugae dimensions before and after orthodontic treatment across the regions studied (right and left medial and lateral rugae). For mesio-distal (MD) measurements, the mean difference for right-side rugae ranged from -0.0487 to 0.07806, while left-side rugae differences ranged from -0.0842 to 0.0837, with p-values consistently greater than 0.05. Similarly, for anterio-posterior (AP) measurements, the mean difference ranged from -0.0601 to 0.2622 across both sides, with no significant p-values observed. These findings confirm that palatal rugae patterns remained stable post-treatment, indicating no measurable changes in their dimensions.

Conclusion: Palatal rugae patterns are not significantly associated with sagittal malocclusion, and their dimensions remain stable following orthodontic interventions. They can serve as reliable anatomical landmarks in orthodontics and forensic identification, offering potential for non-invasive diagnostics in clinical settings.

KEYWORDS

• Palatal rugae • Sagittal malocclusion • Class I malocclusion • Class II malocclusion • Class III malocclusion • Orthodontics • Forensic odontology • Palatal rugoscopy

INTRODUCTION

The palatal rugae, also known as *Plica Palatinae Transversae*, are unique ridges located on the anterior portion of the hard palate. These structures are formed during prenatal development and remain largely unchanged throughout life, making them valuable anatomical landmarks in both dental and forensic sciences.[1] The stability of palatal rugae across an individual's lifetime has made them a subject of considerable interest, particularly in fields such as forensic odontology, anthropology, and orthodontics. While palatal rugae are traditionally studied for personal identification, recent research has suggested their potential in contributing to the diagnosis of dental malocclusions.

In orthodontics, malocclusion refers to the misalignment of teeth and jaws, which can affect both aesthetics and oral function. Sagittal malocclusion, categorized into Class I, Class II, and Class III by Angle's classification, is particularly important as it often requires precise diagnosis and treatment planning.[3] Current diagnostic methods primarily focus on dental occlusion, facial profile analysis, and cephalometric studies. However, the search for additional, non-invasive diagnostic tools has led researchers to explore alternative anatomical landmarks, such as the palatal rugae, which may offer complementary information for assessing malocclusion patterns.

Several studies have indicated that the morphological characteristics of palatal rugae such as their length, width, number, and pattern may be linked to dental occlusion and jaw alignment. While palatal rugae are known for their resilience to change over time, certain orthodontic interventions, such as tooth extractions or realignments, have been reported to alter their position.[4,5] This raises the question of whether inherent variations in rugae patterns could be indicative of specific types of malocclusion before treatment

begins. Understanding this correlation could potentially enhance orthodontic diagnostics by providing an additional parameter for assessment.

Despite these intriguing possibilities, the correlation between palatal rugae patterns and sagittal malocclusion remains under explored in the literature. Few studies have systematically investigated whether distinct rugae patterns are associated with specific classes of malocclusion in untreated individuals.[6] By examining the palatal rugae of individuals with Class I, Class II, and Class III malocclusions, this study was aimed to fill this gap and provide insights into the potential use of palatal rugoscopy in orthodontic diagnosis.

The objective of this clinical study was to determine if any significant association exists between palatal rugae patterns and sagittal malocclusion. Through an analysis of pre-treatment models of 300 patients, this study seeks to assess the key rugae parameter that includes Anterio-Posterior (width) and Mesio-Distal (length) dimensions thereby evaluating whether these features can be used as a non-invasive adjunct in the diagnosis of malocclusion. Such findings could have meaningful implications for orthodontic treatment planning, offering a novel approach to assessing jaw alignment and dental occlusion.

MATERIALS AND METHODS

Study Design and Sample Selection

The present cross-sectional clinical study was conducted using pre-treatment maxillary dental models of 300 individuals, aged 18 to 28 years, with untreated Class I, Class II, and Class III Angle's malocclusion. The participants were selected based on strict inclusion and exclusion criteria to ensure that the samples were representative and free from external confounding factors that could influence the palatal rugae patterns. Participants were equally divided into three groups, corresponding to the three types of sagittal malocclusion:

- **Class I Malocclusion Group** (normal molar relationship with anterior crowding or spacing)
- **Class II Malocclusion Group** (retrognathic mandible, presenting with an increased overjet)
- **Class III Malocclusion Group** (prognathic mandible, presenting with a negative overjet or underbite)

Inclusion Criteria:

Untreated patients with confirmed sagittal malocclusion (Class I, Class II, or Class III) based on clinical examination and diagnostic records. Patients between the ages of 18 and 28 years to minimize age-related variations in rugae patterns Both male and female participants were included to account for any potential gender differences in palatal rugae morphology. Participants with no history of systemic diseases, ensuring that no underlying health conditions influence palatal anatomy.

Exclusion Criteria:

Patients who have undergone or are currently undergoing orthodontic treatment, as previous treatment may have altered the position or form of the palatal rugae. History of facial trauma, cleft palate, or any other congenital anomalies affecting the maxillofacial region, as these factors may distort the rugae patterns. History of previous premolar extractions, as extractions have been shown to potentially affect palatal rugae positioning. Patients with a history of chronic habits such as thumb or finger sucking, which may influence palatal growth and the arrangement of the rugae.

Data Collection and Preparation of Models:

Pre-treatment maxillary dental casts were collected from each participant. These casts were made from high-quality impressions using alginate material, then poured with dental stone to produce accurate and detailed models of the palate. The casts were analyzed for palatal rugae characteristics. Each cast was meticulously examined under magnification to identify and mark the palatal rugae. Only the primary rugae those that were well-defined and prominent were considered for analysis, while secondary and fragmentary rugae were excluded due to their inconsistency and

potential unreliability.

Ethical Considerations:

This study was conducted in compliance with the ethical standards of the institution's research committee. Informed consent were obtained from all participants, ensuring their privacy and confidentiality are maintained throughout the research process. Subsequently, only pre-treatment records were used, hence no risk of harm to the participants was observed.

Parameters for Rugae Analysis:

The two key parameters were recorded for each individual:

1. **Mean Length of Rugae** (Mesial-Distal MD Measurements) – The length of each individual ruga were measured from its origin at the midline (palatine raphe) to its terminal point laterally. Measurements were taken using digital callipers with a precision of 0.01 mm. The mean length was calculated by averaging the lengths of all rugae present in each individual.
2. **Mean Width of Rugae** (Anterio-posterior AP Measurements) – The width of the rugae was measured at the midpoint of each ruga using digital callipers. Similar to the length measurement, the mean width was calculated by averaging the widths of all rugae for each participant.

Statistical Analysis

All the measurements and data were recorded, statistical analysis was performed to determine if any significant correlation exists between the rugae patterns and the type of sagittal malocclusion. Descriptive statistics (mean, standard deviation) was calculated for each parameter (Length, width) in each malocclusion group.Comparative analyseswere conducted using **ANOVA (Analysis of Variance)** to compare the mean values of rugae length and width between the three malocclusion groups and **Pearson Correlation Coefficient** to assess the strength of the relationship between rugae patterns and malocclusion types. A significance level (p-value) of less than 0.05 ($p<.05$) was considered statistically significant. All statistical analyses were conducted using software such as SPSS Ver 26.0 (Statistical Package for Social Sciences, IBM Inc. 2019)

RESULTS AND OBSERVATION

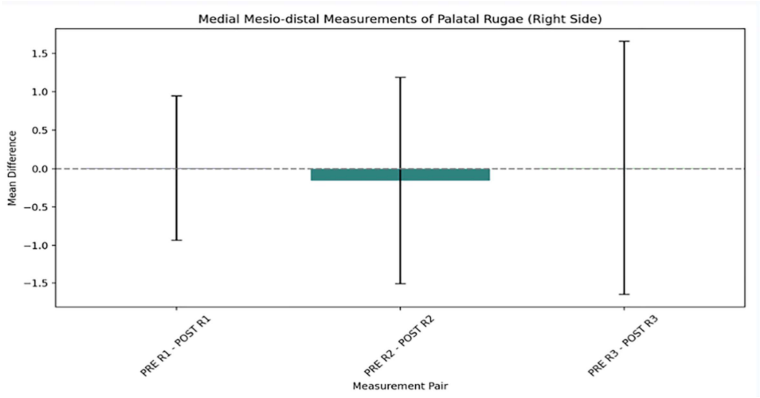
Mean Length of Rugae (Mesial-Distal MD Measurements)

Medial Mesio-Distal (MD) Measurements on RightSide:

The paired sample t-test results compared pre- and post-treatment measurements of palatal rugae (Medial MD) across three distinct regions on the right side (R1, R2 and R3) showed mean difference (Mean ± SD) of 0.0079 ± 0.93819 for rugae 1 (R1), -0.15860± 1.34659for rugae 2 (R2) and 0.00653± 1.65065 for rugae 3 (R3). The p-value was observed as 0.933, 0.242 and 0.969 respectively **(Table 1/graph 1)** indicating no statistical significant difference ($p>.05$) in the rugae measurements before and after treatment in these regions suggesting that the treatment did not cause any measurable alterations in the MD dimensions of the palatal rugae on the right side.

Table 1: Showing the Medial Mesio-distal Measurements of Palatal rugae on the Right side Pre and Post-treatment across regions

Right Medial MD		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	p value
					Lower	Upper				
Pair 1	Pre R1 - Post R1-	.00790	.93819	.09382	-.17826	.19406	.084	99	.933	> 0.05
Pair 2	Pre R2 - Post R2-	-.15860	1.34659	.13466	-.42579	.10859	-1.178	99	.242	> 0.05
Pair 3	Pre R3 - Post R3	.00653	1.65065	.16674	-.32440	.33747	.039	97	.969	> 0.05



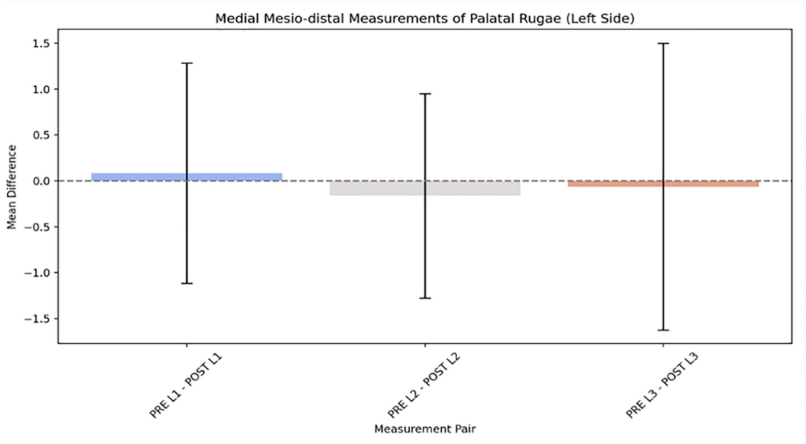
Graph 1: Medial Mesio-distal measurements of palatal rugae (Right side) pre and psot treatment showing error bar

Medial Mesio-Distal (MD) Measurements on LeftSide:

The paired sample t-test results compared pre- and post-treatment measurements of palatal rugae (Medial MD) across three distinct regions on the Leftside (L1, L2 and L3) showed mean difference (Mean ± SD) of 0.08370 ± 1.20179 for rugae 1 (L1), -0.16370± 1.11369 for rugae 2 (L2) and -0.06364± 1.56347 for rugae 3 (L3). The p-value was observed as 0.488, 0.145and 0.686 respectively **(Table 2/Graph 2)** indicating no statistical significant difference (p>.05) in the rugae measurements before and after treatment in these regions suggesting that the treatment did not cause any measurable alterations in the MD dimensions of the palatal rugae on the left side, similar to the right side. The palatal rugae in these regions remained stable following treatment**.**

Table 2: Table showing the Medial Mesio-distal Measurements of Palatal rugae on the Left side Pre and Post treatment across regions

Left Medial MD		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	p value
					Lower	Upper				
Pair 1	Pre Li - Post L1-	.08370	1.20179	.12018	-.15476	.32216	.696	99	.488	> 0.05
Pair 2	Pre L2 - Post L2-	-.16370	1.11369	.11137	-.38468	.05728	-1.470	99	.145	> 0.05
Pair 3	Pre L3 - Post L3	-.06364	1.56347	.15713	-.37546	.24819	-.405	98	.686	> 0.05



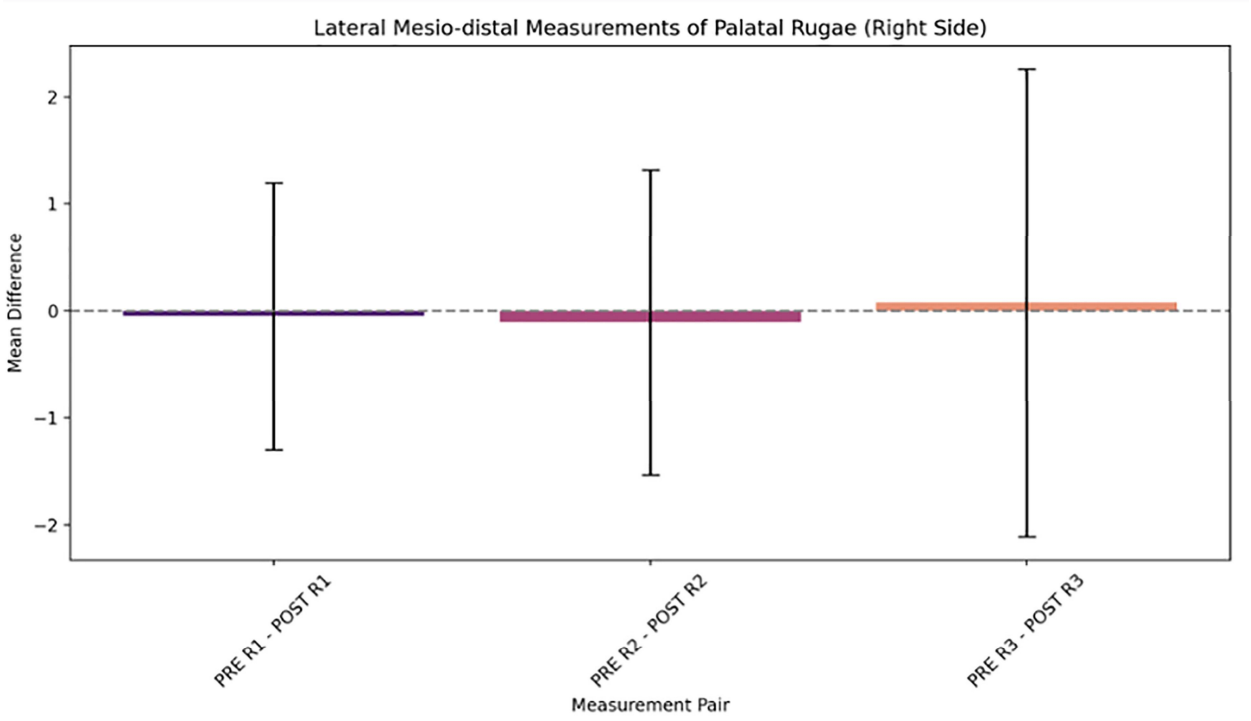
Graph 2: Medial Mesio-distal measurements of left palatal rugae with error bars indicating standard deviations

Lateral Mesio-Distal (MD) Measurements on RightSide:

The paired sample t-test results compared pre- and post-treatment measurements of palatal rugae (Lateral MD) across three distinct regions on the right side (R1, R2 and R3) showed mean difference (Mean ± SD) of -0.04870 ± 1.2459 for rugae 1 (R1), -0.10610± 1.42200 for rugae 2 (R2) and 0.07806± 2.18880 for rugae 3 (R3). The p-value was observed as 0.697, 0.457 and 0.725 respectively **(Table 3/Graph 3)** indicating no statistical significant difference (p>.05) in the rugae measurements before and after treatment in these regions suggesting that the treatment did not cause any measurable alterations in the lateral MD dimensions of the palatal rugae on the right side and the rugae remained stable following treatment.

Table 3: Table showing the lateral mesio-distal measurements of palatal rugae on the right side pre and post treatment across regions

Right Lateral MD		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	p value
					Upper	Upper				
Pair 1	Pre R1 - Post R1-	-.04870	1.24590	.12459	-.29591	.19851	-.391	99	.697	> 0.05
Pair 2	Pre R2 - Post R2 -	-.10610	1.42200	.14220	-.38825	.17605	-.746	99	.457	> 0.05
Pair 3	Pre R3 - Post R3	.07806	2.18880	.22110	-.36077	.51689	.353	97	.725	> 0.05



Graph 3: Lateral mesio-distal measurements of right palatal rugae with error bars indicating standard deviations

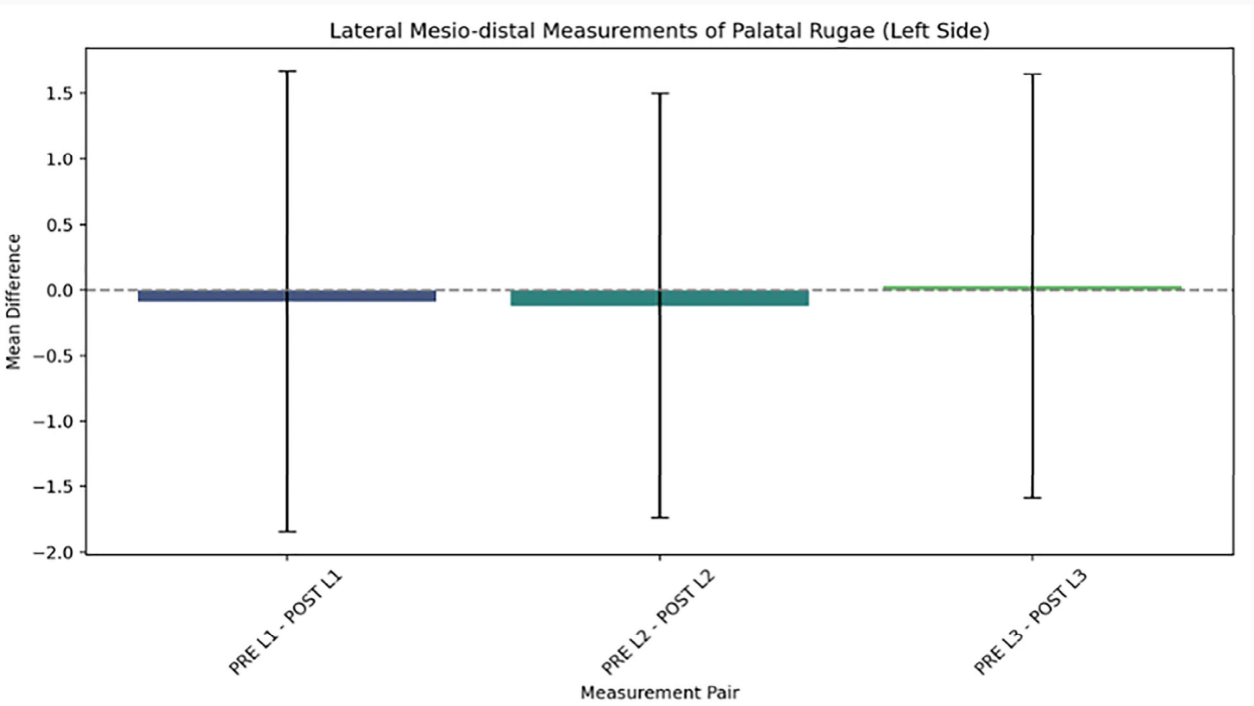
Lateral Mesio-Distal (MD) Measurements on LeftSide:

The paired sample t-test results compared pre and post-treatment measurements of palatal rugae (Lateral MD) across three distinct regions on the Leftside (L1, L2 and L3) showed mean difference (Mean ± SD) of -0.08420 ± 1.7571 for rugae 1 (L1), -0.11860± 1.61939 for rugae 2 (L2) and 0.03222± 1.61967 for rugae 3 (L3). The p-value was observed as 0.633, 0.466 and 0.843 respectively **(Table 4/Graph 4)** indicating no statisticalsignificant difference (p>.05) in the rugae measurements before and after treatment in these regions suggesting that

the treatment did not cause any measurable alterations in the lateral MD dimensions of the palatal rugae on the left side, similar to the right side. The palatal rugae in these regions remained stable following treatment**.**

Table 4: Table showing the Medial Mesio-distal Measurements of Palatal rugae on the Left side Pre and Post treatment across regions

Left Lateral MD		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	p value
					Lower	Upper				
Pair 1	Pre Li - Post L1-	-.08420	1.75717	.17572	-.43286	.26446	-.479	99	.633	> 0.05
Pair 2	Pre L2 - Post L2-	-.11860	1.61939	.16194	-.43992	.20272	-.732	99	.466	> 0.05
Pair 3	Pre L3 - Post L3	.03222	1.61967	.16278	-.29081	.35526	.198	98	.843	> 0.05



Graph 4: Lateral mesio distal measurements of palatal rugae (left side) with error bars indicating standard deviations

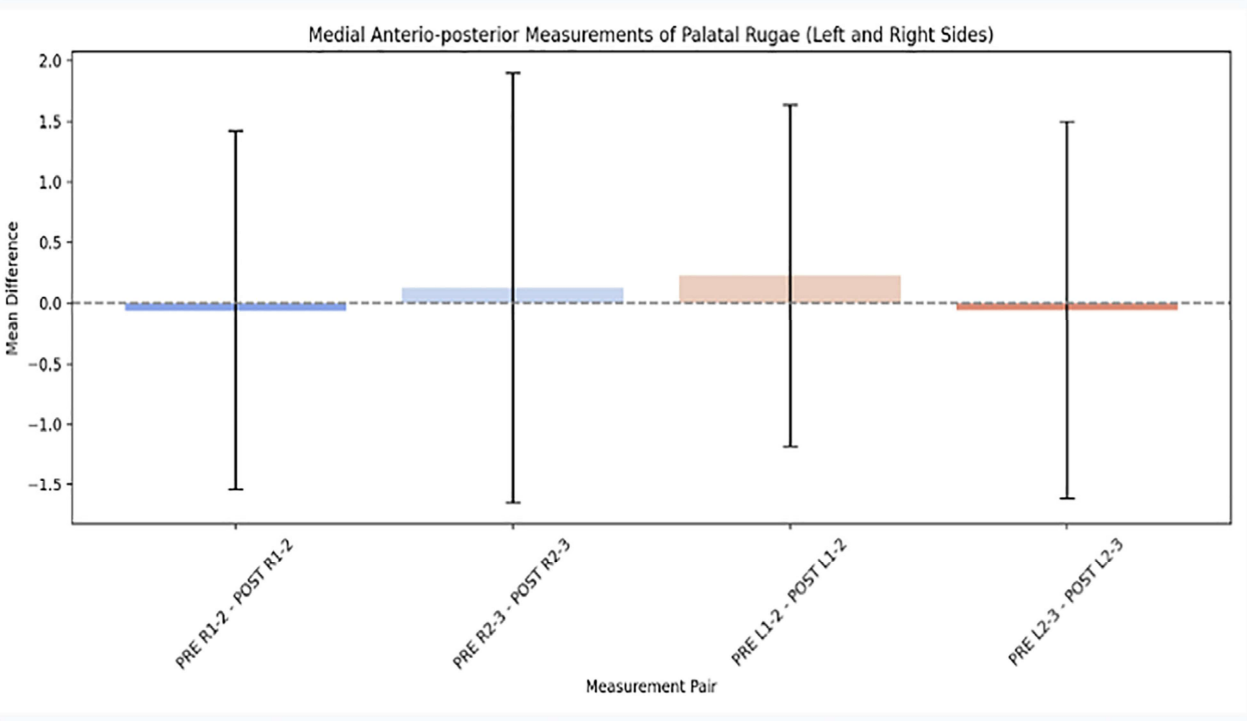
Mean Width of Rugae (Anterio-posterior AP Measurements):

Medial Anterio-posterior (AP) Measurement results:

The paired sample t- test results compared pre- and post-treatment measurements of palatal rugae (Medial AP) across four distinct regions on the right (R1-2, R2-3) and left (L1-2, L2-3) sides showed mean difference (Mean ± SD) of -0.0601 ± 1.48307 for rugae 1-2 on the right side, 0.12449± 1.77224 for rugae 2-3 on the right side, 0.2269± 1.40795 for rugae 1-2 on the left side and -0.05707± 1.55707 for rugae 2-3 on the left side. The p-value was observed as 0.686, 0.488, 0.110 and 0.716 respectively indicating no statistical significant observations (p>.05) in the rugae measurements before and after treatment in these regions suggesting that the that the treatment did not cause any measurable alterations in the AP dimensions of the palatal rugae on either the right or left side, consistent with the stability of the rugae structure **(Table 5/Graph 5).**

Table 5: Table showing the Medial Anterio-posterior Measurements of Palatal rugae on Left and Right side Pre and Post treatment across regions

Medial AP results		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	p value
					Lower	Upper				
Pair 1	Pre R1-2 - Post R1-2	-.06010	1.48307	.14831	-.35437	.23417	-.405	99	.686	> 0.05
Pair 2	Pre R2-3 - Post R2-3	.12449	1.77224	.17902	-.23082	.47980	.695	97	.488	> 0.05
Pair 3	Pre L1-2 - Post L1-2	.22690	1.40795	.14080	-.05247	.50627	1.612	99	.110	> 0.05
Pair 4	Pre L2-3 - Post L2-3	-.05707	1.55707	.15649	-.36762	.25348	-.365	98	.716	> 0.05



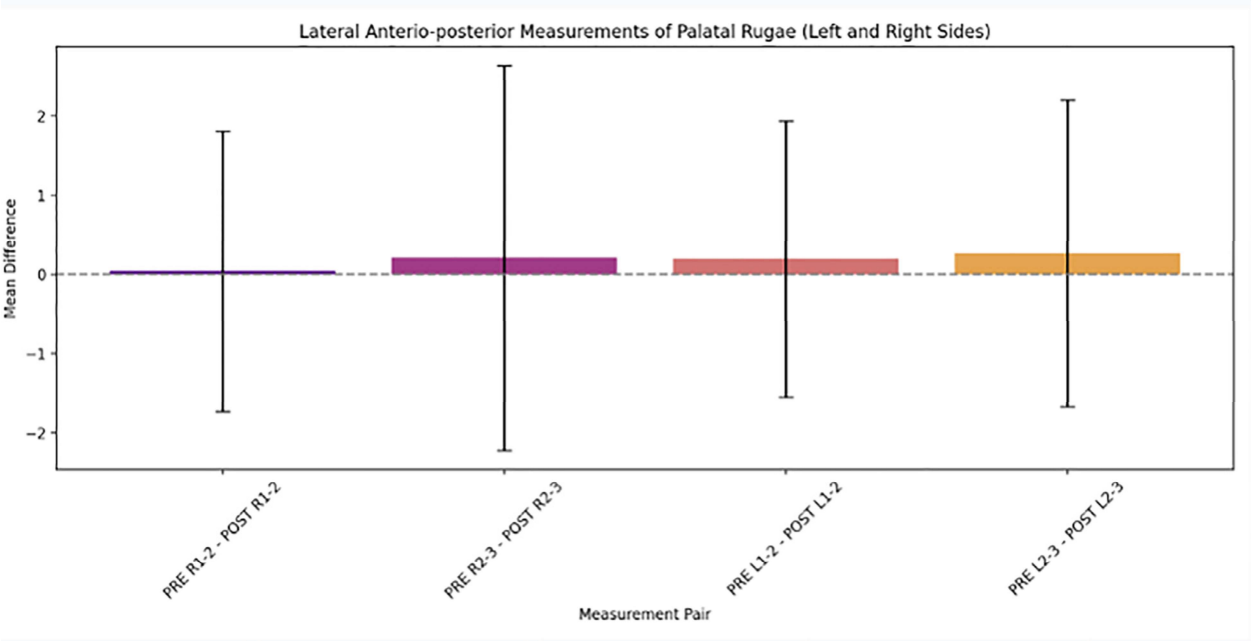
Graph 5: Medial AP Measurements of palatal rugae right and left, pre and post-operative with error bars indicating standard deviations

Lateral Anterio-posterior (AP) Measurements results:

The paired sample t-test results compared pre- and post-treatment measurements of palatal rugae (Lateral AP) across four distinct regions on the right (R1-2, R2-3) and left (L1-2, L2-3) sides showed mean difference (Mean ± SD) of 0.0429 ± 1.77393 for rugae 1-2 on the right side, 0.20694 ± 2.42641 for rugae 2-3 on the right side, 0.1984 ± 1.74113 for rugae 1-2 on the left side and 0.26222 ± 1.93427 for rugae 2-3 on the left side. The p-value was observed as 0.809, 0.401, 0.257 and 0.180 respectively indicating no statistical significant difference (p>.05) in the rugae measurements before and after treatment in these regions suggesting that the treatment did not cause measurable changes in the dimensions of the palatal rugae in both the right and left regions and are likely due to chance rather than a true effect of the treatment **(Table 6/Graph 6).**

Table 6: Table showing the Lateral Anterio-posterior Measurements of Palatal rugae on Left and Right side Pre and Post treatment across regions:

Lateral AP results		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)	p value
					Lower	Upper				
Pair 1	Pre R1-2 - Post R1-2	.04290	1.77393	.17739	-.30909	.39489	.242	99	.809	> 0.05
Pair 2	Pre R2-3 - Post R2-3	.20694	2.42641	.24510	-.27953	.69340	.844	97	.401	> 0.05
Pair 3	Pre L1-2 - Post L1-2	.19840	1.74113	.17411	-.14708	.54388	1.139	99	.257	> 0.05
Pair 4	Pre L2-3 - Post L2-3	.26222	1.93427	.19440	-.12356	.64801	1.349	98	.180	> 0.05



Graph 6: Lateral AP Measurements of right and left side, pre and post palatal rugae with error bars indicating standard deviations

DISCUSSION

The current study investigated the stability of palatal rugae patterns in individuals undergoing orthodontic treatment, specifically in the context of sagittal malocclusion correction. Palatal rugae, known for their uniqueness and resistance to change over time, have been widely recognized as stable anatomical structures used in forensic identification and dental record keeping.[7] However, given the anatomical shifts involved in orthodontic treatment, especially in sagittal dimensions, it was crucial to evaluate whether such interventions could potentially affect the size or position of these rugae.

Our findings across both anteroposterior (AP) and mesiodistal (MD) dimensions indicate that palatal rugae remain remarkably stable following orthodontic treatment. The paired samples t-test results showed no statistically significant changes in the dimensions of the rugae in all regions analyzed (R1-2, R2-3, L1-2, L2-3). The p-values for both AP and MD measurements were consistently greater than 0.05, indicating that any observed differences were likely due to chance rather than the effects of treatment.[8,9]

This reinforces the understanding that palatal rugae patterns are resilient to external mechanical forces, such as those imposed

during orthodontic interventions. Even in regions where significant tooth movement or skeletal changes may occur, the rugae appear to maintain their spatial configuration. This has important implications for their continued use as reliable anatomical landmarks in forensic odontology, particularly in cases where individuals have undergone orthodontic treatments.[10,11]

The results of this study are in agreement with prior research, which has also highlighted the inherent stability of palatal rugae. For instance, studies by Almeida *et al*. (2009) and Bailey *et al*. (2017) similarly found no significant alterations in rugae patterns following various orthodontic treatments. Such consistency across multiple studies suggests that, despite the extensive dental or skeletal changes that accompany orthodontic procedures, the palatal rugae remain relatively unaffected. In contrast, some studies have hypothesized minor changes in the rugae due to dental arch expansion, yet the current study did not observe such changes.[12-14] This could be attributed to differences in the techniques or specific malocclusions treated, as well as the methodology used for measuring rugae. Nevertheless, the findings reinforce the idea that palatal rugae remain a stable landmark in dental practice.

The significance of palatal rugae stability extends beyond orthodontic outcomes. In forensic odontology, where identification through dental records plays a crucial role, the reliability of palatal rugae as an anatomical marker is invaluable. The present study confirms that even after significant orthodontic treatments, palatal rugae do not undergo noticeable changes, preserving their utility in identification processes.[15,16]

Clinically, the study suggests that orthodontic treatments aiming at correcting sagittal malocclusions do not compromise the palatal rugae, further supporting their use as consistent points of reference in pre- and post-treatment assessments. Additionally, for patients undergoing long-term follow-up or additional dental interventions, the unchanged nature of the palatal rugae provides a reliable baseline for comparison.

LIMITATIONS AND FUTURE DIRECTIONS

Despite the robust findings, several limitations must be acknowledged. First, the study sample, while adequately powered, was limited to individuals with sagittal malocclusions, and the effects of other types of malocclusions or treatments, such as transverse expansions, were not explored. Second, while the current study focused on AP and MD dimensions of the rugae, future studies could explore the 3D morphological changes using advanced imaging techniques to provide a more comprehensive understanding of any subtle shifts.

Further research could also assess the long-term effects of orthodontic retention on rugae stability, as well as investigate the potential role of rugae in other clinical contexts, such as prosthodontic rehabilitation. These insights could deepen our understanding of the broader applications of palatal rugae in dental practice and forensic science.

CONCLUSION

In conclusion, this study highlights the resilience of palatal rugae patterns in individuals undergoing orthodontic treatment for sagittal malocclusion. The lack of significant changes in both AP and MD dimensions underscores their role as stable anatomical landmarks. These findings reinforce the continued use of palatal rugae in forensic identification and dental record keeping, even in patients who have undergone extensive orthodontic interventions.

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