

Assessment of Palatal Rugae Pattern and Reproducibility for Application in Forensic Analysis

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Abstract

Introduction: The aim of the study is to investigate the stability of palatal rugae patterns in female and male patients prior and after fixed orthodontic therapy. **Materials and Methods:** Fifty patients (25 males and 25 females) scheduled to undergo fixed orthodontic treatment were selected for this study from the outpatient pool of private dental clinics of Muzaffarpur, Bihar. Pre- and post-orthodontic treatment casts were recorded for each patient. Their casts were analyzed for sex determination analysis and changes in rugae pattern following fixed orthodontic therapy. **Results:** The results of the study showed that females have slightly more rugae than males. The study also demonstrated that the changes occurring with extractions and tooth movement or any other orthodontic treatment do not significantly alter the pattern of the palatal rugae. The overall percentage of correct matches by observers in palatal rugae pattern between the casts of pre- and postorthodontic patients was 88.6% and 95.7%, respectively, with a mean of 90.2% and median of 90%. **Conclusion:** This study found that palatal rugae are sufficiently characteristic to indicate identity through discrimination and may be used for identification purposes.

Keywords: Palatal rugae, Forensic odontology, Sex determination, Orthodontic casts.

INTRODUCTION

Visual identification is the most common method applied in forensic analysis. However, in certain incidences, where hard tissues (teeth) of the oral cavity are lost due to any reason such as trauma, visual means of identification are significant in non-mutilated palatal tissues. Thus, in forensic dentistry, the unique characteristics pattern of palatal rugae can be used as an identification tool.

Palatal rugae refer to a series of transverse ridges on the anterior part of the palatal mucosa. These rugae are present on each side of the median palatal raphe and behind the incisive papilla. Application of palatal rugae patterns for personal identification was suggested by Allen in 1889.^[1]

The term palatal rugoscopy was first proposed by the Spanish investigator Trobo Hermosa.^[2] Identification of palatal rugae pattern is based on classification by Thomas and Kotze^[3] that includes number, length, shape, and identification pattern of rugae.

By determination of length of all rugae, three categories are identified

1. Primary rugae (5–10 mm)

2. Secondary rugae (3–5 mm)
3. Fragmentary rugae (less than 3 mm).

The shapes of individual rugae are classified into four major types

1. Straight – Runs directly from origin to termination
2. Curvy – Simple crescent shape that was curved gently
3. Circular – Definite, continuous ring formation, diameter from origin to termination is considered
4. Wavy – Serpentine form.

The unification pattern is further subdivided into diverging and converging types.^[4]

Diverging pattern occurs when two rugae begin from the same origin but diverge transversely. Converging pattern occurs when two rugae arise from different regions and converge transversely.

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The objective of the present study was to investigate sex variation in palatal rugae patterns and evaluate the reliability of these patterns in human identification by studying pre- and post-operative orthodontic cases.

MATERIALS AND METHODS

The present double-blind prospective study was conducted at Sri Krishna Medical College and Hospital, Muzaffarpur, Bihar. All individuals of the study belonged to the same geographical population of Muzaffarpur, Bihar. A total of 50 (25 males and 25 females) healthy volunteers free from any diagnosed congenital abnormalities, inflammation, and trauma, in the age group of 15–30 years who were scheduled to undergo fixed orthodontic therapy at various private dental clinics were included in the study. An impression of the maxilla was recorded prior and after the completion of the orthodontic treatment. All selected casts from the individuals were free of air bubbles or voids, especially in the anterior one-third of the palate.

Rugae patterns on the study models were delineated using pencil/marker under adequate light and magnification using a hand lens (Figure 1a and b). The casts were distributed randomly among two observers for the determination of sex and stability of rugae pattern. The two observers were not informed whether the casts belong to the same patient, and the casts of the pre-operative orthodontic treatment were then matched with multiple post-treatment casts. The individual observer's analyses were also not disclosed to the other observer. The selection of cast for the study was on a random basis without informing the observer on what kind of study was being performed; this could have brought a selection bias for the study.

For the identification of sex, the classification given by Thomas and Kotze^[3] was used. In addition, the unification pattern was also used. To achieve stability during analyses, each of the observers randomly took one pre-operative cast of a patient who underwent orthodontic treatment and this was matched with multiple post-operative casts on the basis of palatal rugae, and the closest match was selected. Correctness of the match for each examiner was calculated as the percentage.

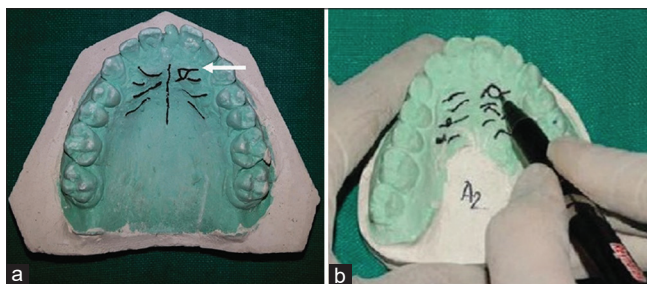


Figure 1: Orthodontic study casts. (a) Pre-orthodontic treatment cast with markings done on rugae. (b) Post-orthodontic treatment cast with markings being made on the cast

RESULTS

The results of the study showed that females have slightly more rugae than males. These sex-wise distribution modes of unification pattern of rugae showed a statistically significant difference. Diverging pattern was found more commonly in females compared with males, who predominantly showed converging patterns (Table 1). This can probably substantiate the increase in rugae pattern in females.

The use of pre- and post-orthodontic cases also demonstrates that the changes occurring with extractions and tooth movement or any other orthodontic treatment do not significantly alter the pattern of the palatal rugae. Variables in length and shape of palatal rugae also showed statistically significant results and thus could be used as a discriminant in sex determination (Table 2). The overall percentage of correct matches by observers in palatal rugae pattern between the casts of pre- and post-operative orthodontic patients was 88.6% and 95.7%, respectively, with a mean of 90.2% and median of 90%. The percentage of correct matches for each case was 74.2% and 100%, respectively, with a mean of 90.32%. To evaluate the accuracy of identification, kappa stats was performed between the observers and the score was 0.61, which indicates an agreement between observers for correctly matching pre-operative and postoperative casts. Further results are summarized from Tables 3-6.

This study found that palatal rugae are sufficiently characteristic to indicate identity through discrimination. This gave the evidence that palatal rugae may be used for identification purposes and was proved to be stable in the population under study.

DISCUSSION

Many attempts have been made to find out safe means for human identification that may allow recognition, avoidance, or detection of errors and simultaneously preclude changes or alterations of numbers or individuals. It is widely acknowledged that there are limitations in identification by fingerprints, dental records, and DNA in some forensic situations and the palatal rugae pattern of an individual may be considered as a useful adjunct for identification purposes. Our study also emphasized the advantage of palatoscopy in accordance to the previous literature. The present study was carried out to study the rugae pattern and to compare the patterns between the males and the females.

We also aimed to evaluate the reliability of palatal rugae as a forensic tool and to assess its stability in a particular regional and ethnic group, as there tends to be variation in various groups. This study found that palatal rugae are sufficiently characteristic to indicate identity through discrimination and gave evidence that palatal rugae may be used for identification purpose and was proven to be stable in the population under study (Figure 1a and b). The average number of rugae in females was slightly higher in comparison with that in males,

Table 1: Difference in age and number of rugae according to gender using independent *t*-test

Groups	Gender	Mean	Standard deviation	Mean difference	95% confidence interval for difference		T	P-value
					Lower	Upper		
Age	Male	15.1200	2.47184	-0.44000	-1.98178	1.10178	-0.574	0.569
	Female	15.5600	2.93087					
Number	Male	8.2400	1.16476	-0.32000	-1.19148	0.55148	-0.738	0.464
	Female	8.5600	1.82757					

Table 2: Difference in shape of rugae according to gender using independent *t*-test

Shape of rugae	Gender	Mean	Standard deviation	Mean difference	95% confidence interval for difference		T	P-value
					Lower	Upper		
Straight	Male	3.0400	1.51327	-0.52000	-1.49511	0.45511	-1.072	0.289
	Female	3.5600	1.89473					
Wavy	Male	2.0800	0.95394	-1.08000	-1.75289	-0.40711	-3.227	0.002
	Female	3.1600	1.37477					
Curved	Male	1.9600	1.33791	0.92000	0.30618	1.53382	3.014	0.004
	Female	1.0400	0.73485					

Table 3: Difference in pre-operative primary, secondary, and fragmentary length of rugae according to gender using independent *t*-test

Shape of rugae	Gender	Mean	Standard deviation	Mean difference	95% confidence interval for difference		T	p
					Lower	Upper		
Primary	Male	8.3324	0.97612	-0.58760	-1.08128	-0.09392	-2.393	0.021
	Female	8.9200	0.74456					
Secondary	Male	3.5552	0.50457	-0.37230	-0.74845	0.00385	-1.991	0.052
	Female	3.9275	0.78045					
Fragmentary	Male	1.8600	0.52579	-0.06391	-0.35551	0.22769	-0.441	0.661
	Female	1.9239	0.47335					

Table 4: Difference in post-operative primary, secondary, and fragmentary length of rugae according to gender using independent *t*-test

Shape of rugae	Gender	Mean	Standard deviation	Mean difference	95% confidence interval for difference		T	P-value
					Lower	Upper		
Primary	Male	9.7344	1.01467	-0.42720	-0.95797	0.10357	-1.618	0.112
	Female	10.1616	0.84416					
Secondary	Male	4.2700	0.52500	-0.27000	-0.55523	0.01523	-1.903	0.052
	Female	4.5400	0.47697					
Fragmentary	Male	3.5200	4.10660	0.54000	-1.14818	2.22818	0.643	0.661
	Female	2.9800	0.87178					

Table 5: Distribution of unification of rugae according to gender using Chi-square test

Unification	Gender		Total	X ²	P-value
	Male	Female			
Convergent	24	4	28	32.468	0.000
Divergent	1	21	22		
Total	25	25	50		

and the diverging pattern was found more commonly in females compared with males.

Souza Lima conducted a study and concluded that there are no changes in the morphology or arrangement of palatal rugae.^[5] Individuals submitted to surgery exhibited a mild reduction of space among the rugae or even shortening or elongation depending on the extent of the intervention performed. There was no remarkable damage in any such case. However, it

Table 6: Difference between pre- and post-operative primary, secondary, and fragmentary length of rugae among females using paired *t*-test

Shape of rugae	Time	Mean	Standard deviation	Mean difference	95% confidence interval for difference		T	P-value
					Lower	Upper		
Primary	Pre-operative	8.9200	0.74456	-1.24160	-1.50504	-0.97816	-9.727	0.000
	Post-operative	10.1616	0.84416					
Secondary	Pre-operative	3.9275	0.78045	-0.63500	-0.91131	-0.35869	-4.754	0.000
	Post-operative	4.5625	0.47348					
Fragmentary	Pre-operative	1.9239	0.47335	-0.96739	-1.27021	-0.66458	-6.625	0.000
	Post-operative	2.8913	0.79710					

should be highlighted that the palatal rugae may be changed by different factors, such as wearing complete dentures, procedures that may cause trauma, cleft palate, fibrous tissue, and “calluses;” however, these factors do not impair identification. In our study also, the rugae pattern remained unchanged after the intervention.

English *et al.*^[6] conducted a study to identify individuals undergoing orthodontic treatment. They concluded that the palatal rugae pattern is characteristic enough to differentiate among individuals. Hauser *et al.*^[7] investigated dental casts of individuals from Swaziland aged 12–60 years. Prominent rugae were observed on the dental casts of this population; the palatal rugae patterns were very similar as this population is highly homogenous. Limsom *et al.*^[8] utilized computer-based recognition software to compare and identify rugae pattern of 250 subjects with a success rate of 92–97%.

Utilization of dental casts presents the advantages of simple analysis, reduced cost, and easy achievement in any laboratory; this corroborates that the routine work of average number of rugae in females was slightly higher in comparison with that in males, and the diverging pattern was found more commonly in females as compared with males. Therefore, anatomical structures such as palatal rugae may have greater importance in the future and could serve as a potential forensic tool as it remains unchanged after the surgical intervention.

CONCLUSION

The present study has clearly highlighted the patterns of rugae architecture that are highly specific for the female

and male populations. The average number of rugae in females was slightly higher in comparison with that in males and the diverging pattern was found more commonly in females compared with males. The study also highlighted the consistency of rugae pattern in pre- and post-treated dental patients (orthodontically treated). Likewise, further studies need to be explored on varying population. The rugae morphological pattern may be useful in forensic science in case of mutilation when compared with other parts of the body. Palatal rugae form an intrinsic and integral pattern for every single individual and can also help in sex determination. The ease of reproducibility and lower level of variation make palatal rugae a potential tool in forensic odontology.

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