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Original Research

Palatal Rugae Patterns in Orthodontically Treated Cases, Are They a Reliable Forensic Marker?

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Abstract:

Background: The specialization of forensic odontology is fast emerging as a branch that helps in personal identification of both living as well as dead individuals and also in crime scene investigations. Establishing a person's identity can be a challenging task in cases of road accidents or acts of terrorism or mass disaster scenario. It is an established fact that palatal rugae are unique for each individual and can be reliably used in the forensic field for personal identification. The present study was undertaken to evaluate the post-treatment stability of palatal rugae pattern in individuals subjected to orthodontic treatment with and without extractions and palatal expansion.

Materials and Methods: A total of 137 pre- and post-orthodontically treated casts of patients were obtained from our institute, which were divided into 50 cases each of extraction and non-extraction, 37 cases of palatal expansion involving both extraction and non-extraction. Palatal rugae patterns of all the cases were compared pre- and post-treatment.

Results: Chi-square test was applied for comparison of changes with respect to shape of rugae patterns. Maximum changes were seen in palatal expansion and extraction group and minimum changes in non-extraction group both on right and left sides. All three groups were compared involving all three parameters by Chi square test. About 89.19% and 84% of the study group showed changes in palatal expansion and extraction cases respectively. Although, a 62% of study subjects showed changes in non-extraction group with a $P = 0.00041$.

Conclusion: Orthodontic treatment has an impact on the stability of palatal rugae so investigator should be aware of this fact when analyzing for identification reasons.

Key Words: Forensic odontology, orthodontic treatment, palatal rugae, stability

Introduction

The specialization of forensic odontology is fast emerging as a branch that helps in personal identification of both living as well as dead individuals and also in crime scene investigations.[1] The personal identification procedure could be needed in case of a dead or a living individual with both the situations having different sets of difficulties. Personal identification is based on a comparison between known records of ante-mortem data with records of post-mortem data.[1,2] The post-mortem identification process is an integral aspect of the medicolegal death investigation, and identifying human remains is important for both legal and humanitarian reasons.[1-3] Establishing an individual's identity can be a tough task in cases of road accidents or acts of terrorism or in mass disaster scenario.[3,4] Visual identification, use of dental records, fingerprints and DNA records probably are the most prevalent techniques used to serve the purpose, providing with swift and reliable identification.[5] However, application of visual identification and use of fingerprints is restricted by post-mortem changes associated with time, temperature changes and humidity. Although teeth are more resistant to environmental changes than other parts of the body, identification through dental records also may prove to be difficult, because dental treatment could have been performed between the procurement of dental records and the individual's decease. Although DNA profiling is precise, it is expensive and time-consuming for use in large populations.[1-4] It is a well-accepted fact that the rugae pattern is as unique to a human as are his or her fingerprints, and the rugae maintain their shape throughout life once formed during 12-14th week of prenatal life and the pattern remains unchanged until the oral mucosa degenerates after death. The anatomical location of the palatal rugae inside the oral cavity–within the blanket of cheeks, lips, buccal pad of fat, dento alveolar apparatus–keeps them protected from trauma and temperature changes. Thus, they can be used as a reliable reference landmark during forensic identification.[6-12] Very few studies have been undertaken to determine the credibility, reliability and stability of rugae patterns in individual identification that could play a very important role in forensic sciences. Controversies exist until date regarding quantitative and qualitative characteristics of rugae following extraction, orthodontic treatment, and denture prosthesis. Previous studies may not have taken into account, the effects of growth, extractions, palatal expansion, or a combination of these. Hence, this study was taken up to evaluate the post-treatment stability of palatal rugae pattern in individuals subjected to orthodontic treatment with and without extractions and palatal expansion.

Materials and Methods

A total of 137 pre- and post-orthodontically treated casts of patients were obtained from our institute, which were divided into 50 cases each of extraction and non-extraction, 37 cases of palatal expansion involving both extraction and nonextraction. All the patients were treated by pre adjusted edgewise therapy. The duration of treatment varied from 8 to 24 months. All impressions were made from alginate impression material and casts were made from dental stone. Rugae pattern on all casts was delineated using a 0.3 mm graphite pencil under adequate light and magnification. Markings were carried out by one operator and cross checked by another operator. Rugae length was recorded under magnification with a digital slide caliper.[13,15]

Lysell and Thomas and Kotze classification was followed to assess palatal rugae pattern.[16,17]

Rugae length involved three categories:
1. Primary rugae: 5 mm or more
2. Secondary rugae: 3-5 mm
3. Fragmentary rugae: 2-3 mm

Rugae measuring <2 mm were not considered.

Rugae shapes were mainly classified into eight major types:[18,19]
1. Annular
2. Branching
3. Converging
4. Cross linking
5. Curved
6. Diverging
7. Linear
8. Wavy.

To assess the intra observer variation in interpretation two observers performed the analysis and mean of two were taken for analysis. Only a few discrepancies were noted involving the fragmentary rugae.

Rugae length, shape and their positions were recorded on both right and left sides of pre- and post-treated orthodontic treated casts and were compared. Obtained results were subjected to statistical analysis.

Results

All three groups were compared for mean and standard deviation.

On right side, not much of a difference was observed in extraction group while there was an increase in length in nonextraction and palatal expansion cases (Tables 1 and 2).

On left side not much difference was observed in nonextraction and palatal expansion groups, but there was a slight increase in length in extraction group (Tables 3 and 4).

Table 1: Mean and SD length in three groups (right side).

Group	Pre-treatment		Post-treatment	
	Means	SD	Means	SD
Extraction	8.7108	3.5109	8.7127	3.5205
Non-extraction	8.7505	3.4461	9.1361	4.0519
Palatal expansion	8.4921	3.3078	9.0155	3.5748

SD: Standard deviation

Comparison of three groups w.r.t length by ANOVA test revealed insignificant difference in mean length within groups and b/w groups were observed from pre- to post-treatment (Tables 2 and 4).

Changes in length in three groups were compared using the paired *t*-test (Tables 5 and 6).

On right side, not much difference was seen in nonextraction group, but an increase in length was seen in both extraction and palatal expansion group. While on left side almost identical length was in extraction and non-extraction group, but there was in a slight increase in palatal expansion group. Chi-square test was applied for comparison of changes w.r.t shape of rugae patterns. Maximum changes were seen in palatal expansion and extraction group and minimum changes in nonextraction group both on right and left sides (Tables 7 and 8). All three groups were compared involving all three parameters using the Chi-square test. About 89.19% and 84% of the study group showed changes in palatal expansion and extraction cases respectively. While, a 62% of study subjects showed changes in nonextraction group with a $P = 0.00041$ (Table 9).

Discussion

The amount of tooth movement seems to have some influence on the stability of palatal rugae.[14,20-26] In the present study, post-treatment changes were seen in the majority of the cases w.r.t size, shape, position, number and gross appearance of rugae in all the examined cases. Although when subjected to statistical analysis, involving parameter of length, they were not found to be statistically significant on either sides (Graphs 1-4). Although not statistically significant, maximum changes were seen in palatal expansion cases. The shape aspect of the rugae was analyzed on both sides. Palatal expansion cases presented with a maximum change in the rugae pattern but the differences in the study groups were not statistically significant (Graphs 5-8). When all the parameters considered together were subjected for statistical analysis, the changes were found to be statistically significant with a $P = 0.00041$, which is not concurrent with previous studies. The contradiction in the result with previous studies can be attributed to the fact that earlier studies did not include the palatal expansion cases, and systematic categorization of cases was not done. The group involving palatal expansion cases has shown changes of the

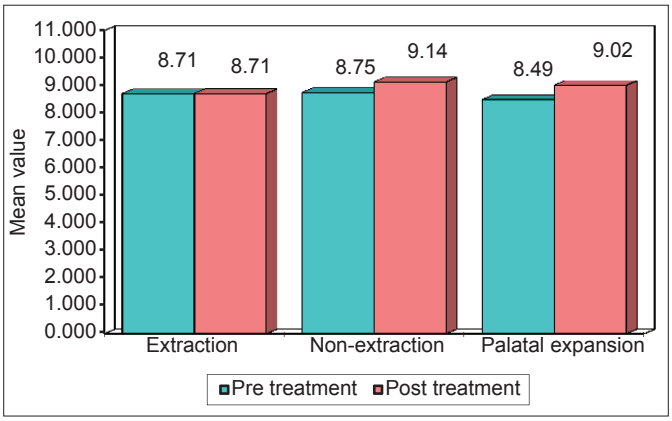
Table 2: Comparison of extraction, non-extraction and palatal expansion with respect to right side length by ANOVA test.

Variable	Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	*F* value	*P* value
Pre-treatment	Between groups	2	6.48	3.242	0.2755	0.7593
	Within groups	542	6377.96	11.767		
	Total	544	6384.45			
Post-treatment	Between groups	2	18.26	9.128	0.6518	0.5215
	Within groups	541	7576.38	14.004		
	Total	543	7594.63			
Change	Between groups	2	22.06	11.028	0.8289	0.4371
	Within groups	542	7211.23	13.305		
	Total	544	7233.29			

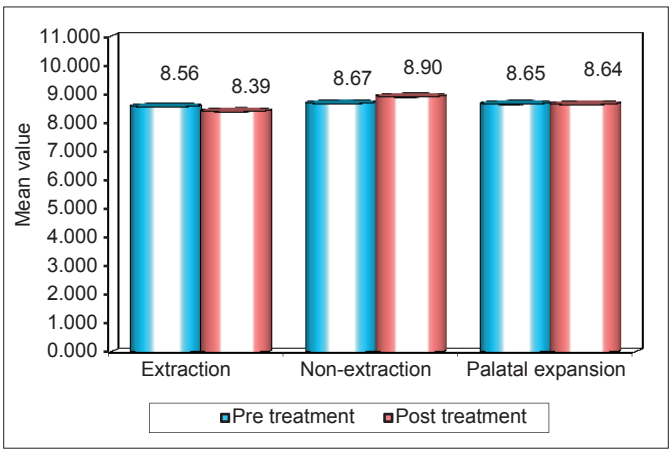
Table 3: Mean and SD length in three groups (left side).

Group	Pre-treatment		Post-treatment	
	Means	SD	Means	SD
Extraction	8.5582	2.9954	8.3940	3.1709
Non-extraction	8.6702	3.3137	8.9042	3.3790
Palatal expansion	8.6515	3.1582	8.6382	3.3667

SD: Standard deviation

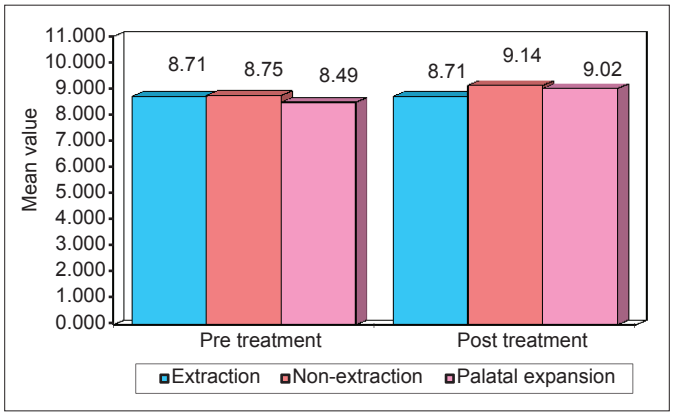


Graph 1: Comparison of extraction, non-extraction and expansion with respect to right side length.

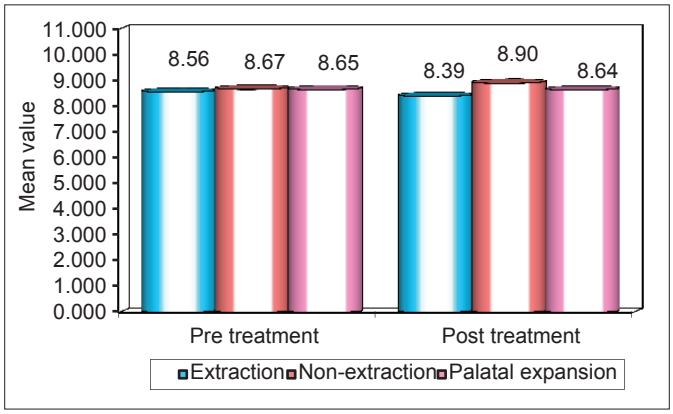


Graph 2: Comparison of extraction, non-extraction and palatal expansion with respect to left side length.

highest magnitude (89.19%), and then extraction group (84.00%) and least changes involving non extraction group (62.00%), (Graph 9 and Table 9). Similar study was carried out by Bansode *et al.*[7] came up with results contradictory to



Graph 3: Comparison of pre- and post-treatment with respect to length values in three groups i.e., extraction, non-extraction and palatal expansion group in right side.



Graph 4: Comparison of pre- and post-treatment with respect to length values in three groups i.e., extraction, non-extraction and palatal expansion group in left side.

our study that contained few palatal expansion cases. The palatal expansion cases in the study done by Bansode *et al.* showed changes only in the length of palatal rugae. The stability of the first and second palatal rugae is limited and dependent on the type of orthodontic treatment. As stated by Peavy and Kendrick 'the closer the rugae are to the teeth, the more prone they are to stretch in the direction that their associated teeth move.'[21] These findings are also consistent with those of Van der Linden and Almeida *et al.*[20,21] In Palatal expansion cases there will be a significant increase in arch perimeter subsequently causing changes in the shape, size

Table 4: Comparison of extraction, non-extraction and palatal expansion with respect to left side length by ANOVA test.

Variable	Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	*F* value	*P* value
Pre-treatment	Between groups	2	1.41	0.706	0.0706	0.9318
	Within groups	559	5589.54	9.999		
	Total	561	5590.95			
Post-treatment	Between groups	2	26.37	13.184	1.2074	0.2997
	Within groups	559	6103.78	10.919		
	Total	561	6130.15			
Change	Between groups	2	16.37	8.184	0.8428	0.4310
	Within groups	559	5427.83	9.710		
	Total	561	5444.20			

Table 5: Comparison of pre- and post-treatment with respect to length values in three groups i.e., extraction, non-extraction and palatal expansion group in right side by paired *t*-test.

Group	Treatment	Mean	SD	Mean difference	SD difference	Paired *t*-test	*P* value
Extraction	Pre	8.7108	3.5109	−0.0019	3.0770	−0.0083	0.9934
	Post	8.7127	3.5205				
Non-extraction	Pre	8.7505	3.4461	−0.3855	3.9774	−1.3810	0.1688
	Post	9.1361	4.0519				
Palatal expansion	Pre	8.4959	3.3184	−0.5195	3.7826	−1.6990	0.0914
	Post	9.0155	3.5748				

SD: Standard deviation

Table 6: Comparison of pre and post-treatment with respect to length values in three groups i.e., extraction, non-extraction and palatal expansion group in left side by paired *t*-test.

Group	Treatment	Mean	SD	Mean difference	SD difference	Paired *t*-test	*P* value
Extraction	Pre	8.5582	2.9954	0.1641	2.7161	0.8460	0.3986
	Post	8.3940	3.1709				
Non-extraction	Pre	8.6702	3.3137	−0.2340	3.3382	−1.0133	0.3121
	Post	8.9042	3.3790				
Palatal expansion	Pre	8.6515	3.1582	0.0133	3.2732	0.0510	0.9594
	Post	8.6382	3.3667				

SD: Standard deviation

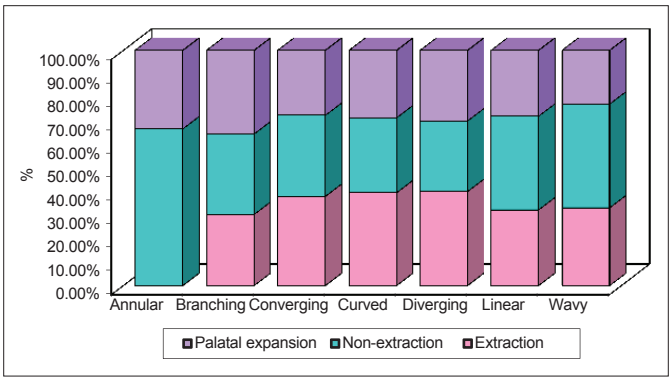
Table 7: Comparison of three groups with respect to shape of rugae patterns at pre- and post-treatment at right side.

Treat	Rugae patterns	Extraction (%)	Non-extraction (%)	Pal extraction (%)	Total (%)	*P* value
Pre	Annular	0 (0.00)	2 (0.98)	1 (0.65)	3 (0.55)	Chi-square=10.0120
	Branching	23 (12.23)	26 (12.75)	27 (17.65)	76 (13.94)	df=12
	Converging	11 (5.85)	10 (4.90)	8 (5.23)	29 (5.32)	*P*=0.61490
	Curved	62 (32.98)	50 (24.51)	45 (29.41)	157 (28.81)	
	Diverging	4 (2.13)	3 (1.47)	3 (1.96)	10 (1.83)	
	Linear	46 (24.47)	57 (27.94)	40 (26.14)	143 (26.24)	
	Wavy	42 (22.34)	56 (27.45)	29 (18.95)	127 (23.30)	
	Cross linking					
	Total	188 (100.00)	204 (100.00)	153 (100.00)	545 (100.00)	
Post	Annular	1 (0.53)	2 (0.98)	2 (1.31)	5 (0.92)	Chi-square=8.8041
	Branching	15 (7.98)	27 (13.24)	18 (11.76)	60 (11.01)	df=14
	Converging	20 (10.64)	11 (5.39)	11 (7.19)	42 (7.71)	*P*=0.84334
	Curved	53 (28.19)	56 (27.45)	42 (27.45)	151 (27.71)	
	Diverging	5 (2.66)	3 (1.47)	4 (2.61)	12 (2.20)	
	Linear	53 (28.19)	57 (27.94)	43 (28.10)	153 (28.07)	
	Wavy	40 (21.28)	47 (23.04)	31 (20.26)	118 (21.65)	
	Cross linking	1 (0.53)	1 (0.49)	2 (1.31)	4 (0.73)	
	Total	188 (100.00)	204 (100.00)	153 (100.00)	545 (100.00)	

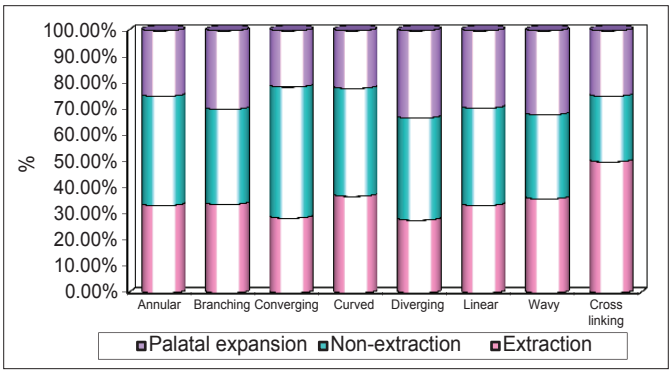
and position of rugae patterns. Extraction of premolars creates a large space for distal retraction of the maxillary anterior teeth, which changes the positions of rugae.[14] The third rugae appeared fairly stable in all measurements and their position near the molar region away from the distal retraction of the anterior teeth may contribute to the lack of change.[22-26] These results were consistent with Schwarze *et al* and Paevy and Kendrick.[21,27] They concluded that

Table 8: Comparison of three groups with respect to shape of rugae patterns at pre- and post-treatment at left side.						
Treat	**Rugae patterns**	**Extraction (%)**	**Non-extraction (%)**	**Pal extraction (%)**	**Total (%)**	***P* value**
Pre	Annular	4 (2.04)	5 (2.39)	3 (1.90)	12 (2.13)	Chi-square=7.1482
	Branching	27 (13.78)	29 (13.88)	24 (15.19)	80 (14.21)	df=14
	Converging	4 (2.04)	7 (3.35)	3 (1.90)	14 (2.49)	*P*=0.92884
	Curved	52 (26.53)	58 (27.75)	31 (19.62)	141 (25.04)	
	Diverging	5 (2.55)	7 (3.35)	6 (3.80)	18 (3.20)	
	Linear	53 (27.04)	59 (28.23)	47 (29.75)	159 (28.24)	
	Wavy	47 (23.98)	42 (20.10)	42 (26.58)	131 (23.27)	
	Cross linking	4 (2.04)	2 (0.96)	2 (1.27)	8 (1.42)	
	Total	196 (100.00)	209 (100.00)	158 (100.00)	563 (100.00)	
Post	Annular	3 (1.53)	5 (2.39)	3 (1.90)	11 (1.95)	Chi-square=11.0042
	Branching	18 (9.18)	25 (11.96)	13 (8.23)	56 (9.95)	df=14
	Converging	5 (2.55)	6 (2.87)	3 (1.90)	14 (2.49)	*P*=0.68574
	Curved	62 (31.63)	61 (29.19)	53 (33.54)	176 (31.26)	
	Diverging	5 (2.55)	8 (3.83)	6 (3.80)	19 (3.37)	
	Linear	60 (30.61)	55 (26.32)	49 (31.01)	164 (29.13)	
	Wavy	37 (18.88)	48 (22.97)	30 (18.99)	115 (20.43)	
	Cross linking	6 (3.06)	1 (0.48)	1 (0.63)	8 (1.42)	
	Total	196 (100.00)	209 (100.00)	158 (100.00)	563 (100.00)	

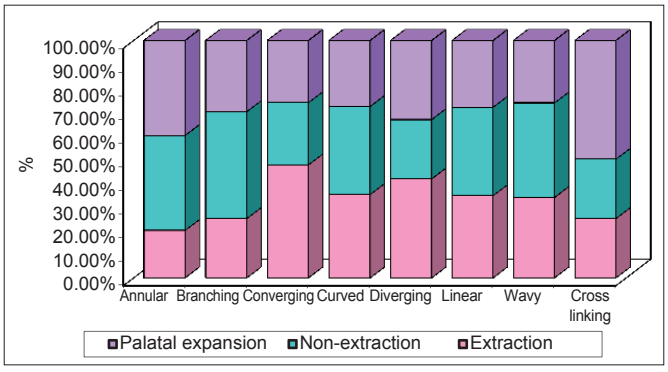
Table 9: Comparison of three groups with respect to status changes.					
Results	**Extraction (%)**	**Non-extraction (%)**	**Palatal expansion (%)**	**Total (%)**	***P* value**
Changed	42 (84.00)	31 (62.00)	33 (89.19)	106 (77.37)	Chi-square=10.9542 df=2 *P*=0.00041, S
Not changed	8 (16.00)	19 (38.00)	4 (10.81)	31 (22.63)	
Total	50 (100.00)	50 (100.00)	37 (100.00)	137 (100.00)	



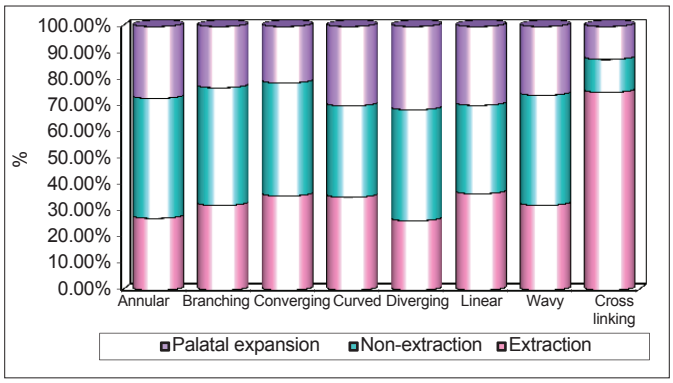
Graph 5: Comparison of three groups with respect to shape of rugae patterns in pre-treatment at right side.



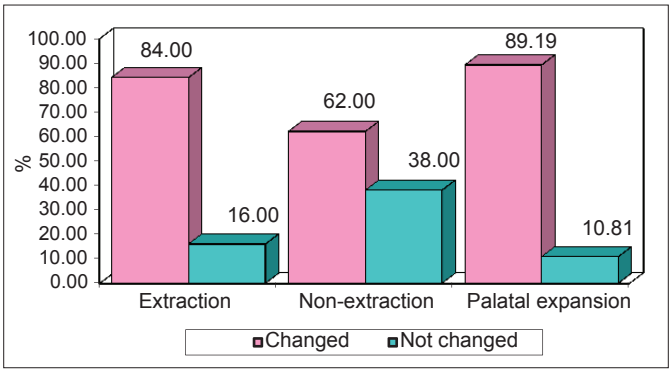
Graph 7: Comparison of three groups with respect to shape of rugae patterns in pre-treatment at left side.



Graph 6: Comparison of three groups with respect to shape of rugae patterns in post-treatment at right side.



Graph 8: Comparison of three groups with respect to shape of rugae patterns in post-treatment at left side.



Graph 9: Comparison of three groups with respect to status changes.

more posterior the rugae are, lesser susceptible are they to changes with tooth movement. Most significant changes were observed in cases involving both extraction and palatal expansion, whereas in cases of non-extraction the changes in rugae pattern remain unexplained.

Conclusion

Palatal rugae pattern is unique to an individual and it can therefore be used in establishing identity which can be an adjunct in forensic medicine provided antemortem data are available.[7] Orthodontic treatment has an impact on stability of palatal rugae so investigator should be aware of this fact when analyzing for identification reasons. Most reliable and stable points being third rugae, they could be used as reference points to evaluate tooth movements.[28] More elaborate studies with larger sample size in a prospective manner and with better rugae evaluation techniques should be carried out to substantiate the beneficial role of palatal rugae in forensic sciences. As, only a very small percentage of individuals with malocclusion undergo orthodontic treatment it would be unjust to write off the role and significance of palatal rugae patterns in individual identification. Having said that, the role of palatal rugae in individual identification in individuals who have undergone palatal expansion remains questionable.

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