Stability of the palatal rugae as landmarks for analysis of dental casts in extraction and nonextraction cases

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The difficulty of identifying stable reference planes that allow superimposition of serial cast data in three planes of space has limited the number of studies employing dental casts to evaluate treatment changes over time. In large part, this is due to the lack of identifiable stable reference points. The palatal rugae may be an appropriately stable landmark.[1]

As early as 1955 Lysell suggested that the palatal rugae might possess unique characteristics that could be used in paternity identification.[2] Hausser suggested that the palatal rugae were displaced sagittally about half as much as the teeth during orthodontic treatment.[3,4] Carrea found that extractions had no effect on the shape of the rugae.[5]

Paevy and Kendrick evaluated the changes in 15 patients treated with the extraction of four premolars and found that the lateral ends of the rugae terminate close to the teeth and tend to follow the movement of the teeth in the sagittal plane but not in the transverse plane. Although the medial termination of the rugae were not evaluated, the authors suggested that while the rugae may be of value as an aid in the orientation of recording devices when evaluating dental changes in longitudinal studies, they were of limited value in determining the magnitude and

Abstract

To determine whether the positions of the palatal rugae were affected by orthodontic therapy, pre- and posttreatment maxillary dental casts of 57 adult patients treated in the graduate orthodontic clinic at the University of North Carolina were evaluated. The orthodontic extraction group (n=27) was composed of patients whose treatment included the extraction of two maxillary premolars. The remaining patients (n=30) had been treated without extractions. Transverse changes observed over time were significantly different from zero only for the medial points of the first rugae in the nonextraction group and for the lateral points of the first rugae in the extraction group. None of the changes observed in the transverse measures were statistically different between the two groups. In the extraction group, there were significant anteroposterior changes in the right lateral points between the first and second rugae and between the second and third rugae, and in the right medial points between the second and third rugae. There were no statistically significant anteroposterior changes observed in the nonextraction group over time. When the two groups were compared, the average distance between the lateral first and second right rugae, and the average distance between the lateral second and third right rugae were significantly different. The medial and lateral points of the third rugae appear to be stable landmarks for the construction of anatomic reference points in longitudinal cast analysis.

Key Words

Palatal rugae • Stability • Dental cast analysis

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Table 1
Demographic characteristics of the two patient groups

Groups	n	Males	Females	Mean age (years)	Age range (years)	Treatment time (months)
Extraction	27	5	22	26.8	18 - 38	12 - 43
Nonextraction	30	6	24	25.6	18 - 36	8 - 38

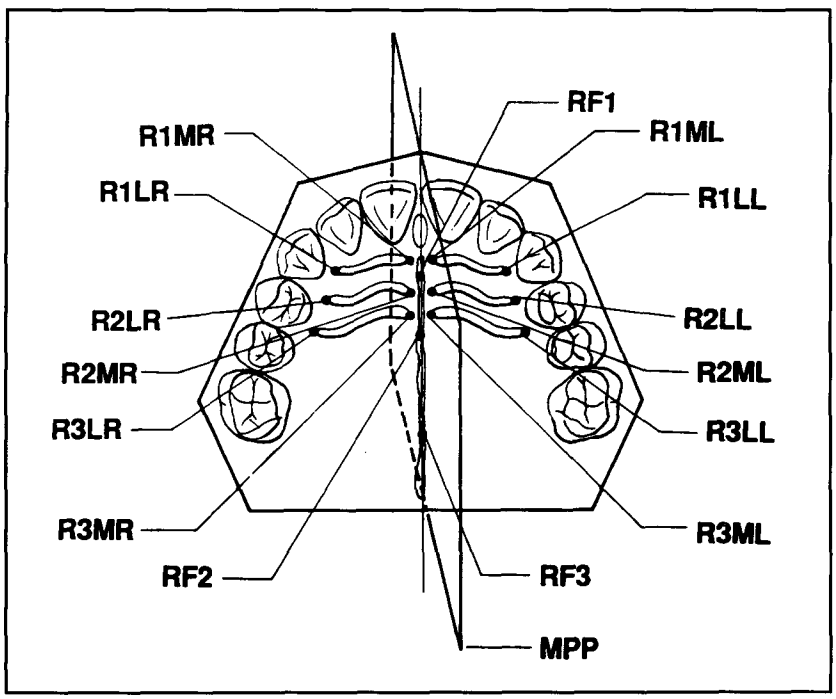

Figure 1
Landmarks marked on the casts: points are located on the median palatal raphe and the most medial and lateral end points of each of the palatal rugae. The median palatal plane (MPP) is constructed as a line that passes through RF1, RF2, and RF3.

direction of tooth movement.[6]

The use of palatal rugae as reference points for serial studies has been thwarted in previous investigations by small sample sizes and the impact of growth on the use of selected reference planes. Almeida et al.,[7] using the Reflex Metrograph to digitize dental casts in three dimensions, conducted a study to determine if the palatal rugae are affected by treatment with headgear or functional appliances as compared with an untreated control group. The transverse offset and linear distances between medial points of the first rugae and the anteroposterior distances between the medial points of the second and third rugae were stable in all groups. Significant changes were observed for the lateral points of the rugae, particularly in the headgear group. The medial rugae appeared to be suitable anatomic landmarks for the construction of stable reference planes for longitudinal cast analyses.

The current investigation extends the previous study to evaluate the effects of extraction on the position of the palatal rugae. The goal of this study was to compare positional changes of the palatal rugae between patients treated orthodontically with extraction of maxillary premolars with those treated without extractions.

Materials and methods

Subjects

Initial and final (defined as end of treatment) casts from 57 adult patients, ranging in age from 18 to 36 and treated in the graduate clinic at the University of North Carolina, were studied. This age range was selected to include patients with fully developed jaws and mature dentitions at the beginning of treatment. The extraction group consisted of 27 patients whose treatment included the extraction of two maxillary premolars. All extraction patients were treated with fixed orthodontic appliances and subsequent retraction of the maxillary anterior teeth into the extraction spaces. The nonextraction patients were treated by conventional edgewise techniques.

The demographic characteristics of the two groups are given in Table 1.

Cast analysis

Landmarks (Figure 1) on the palatal raphe and palatal rugae were carefully marked on the maxillary casts using a 0.3 mm graphite pencil to avoid damage. Initial and final maxillary casts were positioned side by side when landmarks were marked because the landmarks, especially the rugae points, show different patterns of shape, size, and position between patients. If the location of any landmark was doubtful, it was denoted as missing.

The landmarks on each cast were digitized using the Reflex Metrograph (Ross Instruments Ltd, Slaisbury, Wilts, England) by one operator (AE). Landmark location followed the protocol previously outlined by Almedia.[7] The digitizing method error for the X-Y-Z coordinates of four points was calculated, using Dahlberg's method,[8] from 12 digitizing replications with at least two hours between digitizing sessions. The method error was small in all three dimensions and was lowest for the z-coordinate. The range for x-coordinate was 0.02 to 0.10 mm, for y-coordinate 0.09 to 0.24 mm, while the z-coordinate ranged from 0.01 to 0.10 mm.

A median palatal plane (MPP) was constructed from digitized coordinates of landmarks (Figure 1) on the median palatal raphe. Perpendicular distances from MPP plane to the ruga points (off-

sets) were calculated on each cast. In addition, transverse linear distances between medial points and between lateral points of the right and left rugae, as well as right and left anteroposterior (AP) linear distances between medial and between lateral points of the first, second, and third rugae were calculated. Changes from the initial to the final records were calculated for the transverse offset, transverse linear, and AP linear measures.

Statistical analysis

A multivariate analysis of variance using Wilk's Lambda statistic on the three types of measures (transverse offset,transverse linear, and AP linear) was used to assess whether the two groups of patients differed in rugae position prior to the start of the study. Initial measurements for the two groups are shown in Tables 2, 3, and 4. There were no statistically significant differences between the two groups in the baseline measures. Unpaired t-tests were used to evaluate whether the average changes in positions of the rugae during the treatment period was the same for the two groups. Paired t-tests were performed within each group to evaluate whether the average change was different from zero. The level of significance was set at 0.01 for all analyses because of the number of comparisons performed.

Results

Means, standard deviations, and minimum and maximum values for the transverse offset changes are presented in Table 5. The average change observed over time was statistically significant for the offset distance between the medial point of the first rugae in the nonextraction group and between the lateral points of the first rugae in the extraction group. The changes observed in the remaining transverse offsets were not statistically significant in either group, and none of the changes were significantly different between the two groups.

Table 6 shows the descriptive statistics for the transverse linear changes. The results were similar to the offset values; with the change between the medial points of the first rugae in the nonextraction group and the lateral points of the second rugae and the lateral points of the first rugae in the extraction group being significantly different from zero. None of the changes were significantly different between the two groups.

Values for anteroposterior changes are presented in Table 7. In the extraction group, the average changes observed over time were significant for the distances between the lateral points of the first and second right rugae, the lat-

Table 2
Mean and standard deviation for the initial offset measurements of the rugae for each group (mm)

Offset measures	Extraction x̄	Extraction S.D.	Nonextraction x̄	Nonextraction S.D.
1st ruga medial right	1.54	1.09	1.34	0.97
1st ruga lateral right	9.18	1.42	8.84	1.55
1st ruga medial left	-1.62	1.16	-1.53	1.05
1st ruga lateral left	-9.15	1.55	-8.96	1.25
2nd ruga medial right	2.19	1.43	2.02	1.78
2nd ruga lateral right	10.12	1.39	9.97	1.68
2nd ruga medial left	-3.06	2.07	-2.99	1.78
2nd ruga lateral left	-10.43	1.46	-9.89	1.68
3rd ruga medial right	4.07	2.77	4.24	2.65
3rd ruga lateral right	10.98	1.72	11.10	1.92
3rd ruga medial left	-4.40	2.71	-4.39	2.46
3rd ruga lateral left	-11.12	1.51	-11.88	1.39

P= 0.32 Wilk's Multivariate

Table 3
Mean and standard deviation for the initial transverse linear measurements between bilateral ruga points (mm) for each group

Transverse linear measures	Extraction x̄	Extraction S.D.	Nonextraction x̄	Nonextraction S.D.
1st ruga medial	4.38	2.30	3.68	1.82
1st ruga lateral	18.50	2.68	17.97	2.17
2nd ruga medial	6.76	2.45	6.71	2.52
2nd ruga lateral	20.88	2.49	20.22	2.53
3rd ruga medial	9.57	3.55	9.36	3.66
3rd ruga lateral	22.69	2.51	23.54	2.50

P=1.45 Wilk's Multivariate

Table 4
Mean and standard deviation for the initial AP measurements between ruga points (mm) for each group

AP measures	Extraction x̄	Extraction S.D.	Nonextraction x̄	Nonextraction S.D.
1st - 2nd medial right	3.49	1.76	4.09	2.02
2nd - 3rd medial right	6.01	2.66	5.91	3.04
1st - 2nd medial left	4.42	2.17	5.68	1.99
2nd - 3rd medial left	5.60	2.07	5.21	1.73
1st - 2nd lateral right	5.21	2.98	5.19	2.15
2nd - 3rd lateral right	6.12	3.36	5.71	2.61
1st - 2nd lateral left	5.19	2.46	4.70	2.33
2nd - 3rd lateral left	4.68	2.23	5.34	2.37

P=0.62 Wilk's multivariate

Table 5
Descriptive statistics for the transverse offset changes of the ruga points (mm) for each of two groups (positive values indicate expansion and negative values indicate constriction)

Offset changes	Groups	$\bar{x}$	S.D.	Max	Min	P+	P*
1st ruga medial	Ext	0.18	0.58	1.53	-0.88	0.11	0.12
	Nonext	0.41	0.49	1.36	-0.44	0.001	
1st ruga lateral	Ext	0.84	1.64	6.34	-1.55	0.01	0.10
	Nonext	0.24	1.04	2.52	-3.01	0.22	
2nd ruga medial	Ext	0.34	0.94	3.14	-1.30	0.07	0.16
	Nonext	0.05	0.58	1.34	-1.22	0.65	
2nd ruga lateral	Ext	0.34	1.26	4.11	-1.51	0.17	0.85
	Nonext	0.39	0.87	2.48	-1.95	0.02	
3rd ruga medial	Ext	-0.13	0.89	3.25	-1.96	0.47	0.59
	Nonext	0.00	0.85	2.64	-2.35	0.98	
3rd ruga lateral	Ext	0.21	1.64	4.68	-2.30	0.50	0.70
	Nonext	0.35	1.06	2.99	-2.53	0.08	

+P value from paired t-test to assess change over time
*P value from unpaired t-test to assess whether changes are the same for two groups

Table 6
Descriptive statistics for the transverse linear changes (mm) between bilateral ruga points for two groups (positive values indicate expansion and negative values indicate constriction)

Transverse linear changes	Groups	$\bar{x}$	S.D.	Max	Min	P+	P*
1st ruga medial	Ext	0.13	0.73	1.71	-1.48	0.36	0.12
	Nonext	0.39	0.51	1.91	-0.45	0.0002	
1st ruga lateral	Ext	0.84	1.64	6.31	-1.44	0.01	0.10
	Nonext	0.23	1.08	2.50	-3.13	0.25	
2nd ruga medial	Ext	0.04	0.80	2.31	-1.40	0.80	0.72
	Nonext	-0.04	0.92	1.79	-3.90	0.80	
2nd ruga lateral	Ext	0.26	1.31	4.15	-1.55	0.31	0.57
	Nonext	0.43	0.89	2.30	-1.33	0.01	
3rd ruga medial	Ext	-0.11	0.95	3.77	-2.20	0.54	0.64
	Nonext	0.00	0.87	2.45	-2.13	1.00	
3rd ruga lateral	Ext	0.15	1.69	4.93	-2.39	0.64	0.75
	Nonext	0.27	1.15	3.27	-2.47	0.21	

+P value from paired t-test to assess change over time
*P value from unpaired t-test to assess whether changes are the same for two groups

eral points of the second and third right rugae, and the medial points of the second and third right rugae. There were no statistically significant changes observed in the nonextraction group. The average change between the lateral first and second right rugae and between the lateral second and third right rugae were significantly different for the two groups.

Discussion

The amount of tooth movement seems to have some influence on the stability of palatal rugae. The extraction of one or two premolars creates a large space for distal retraction of the maxillary anterior teeth, which apparently changes the positions of the lateral points of the first rugae, and this changes the transverse offset and linear values. None of the medial points of the first rugae were affected in the extraction group for the

Table 7
Descriptive statistics for AP changes (mm) between medial and lateral points of the rugae (positive values indicate expansion and negative values indicate constriction)

	Extraction					Nonextraction					P*
AP changes	$\bar{x}$	S.D.	Max	Min	P+	$\bar{x}$	S.D.	Max	Min	P+	
1st - 2nd medial right	0.05	0.64	2.00	-1.05	0.67	-0.07	0.69	2.23	-0.92	0.58	0.49
1st - 2nd medial left	-0.21	1.04	3.74	-2.00	0.30	-0.05	0.69	1.40	-1.52	0.68	0.50
1st - 2nd lateral right	-0.70	0.97	1.04	-2.29	0.001	0.03	0.70	1.37	-1.47	0.82	0.002
1st - 2nd lateral left	-0.65	1.65	4.01	-5.03	0.05	-0.13	0.65	1.86	-1.10	0.29	0.12
2nd - 3rd medial right	-0.47	0.48	0.37	-1.45	0.001	-0.13	0.58	1.33	-1.09	0.24	0.02
2nd - 3rd medial left	-0.08	0.74	0.99	-2.50	0.58	-0.01	0.34	0.74	-0.58	0.86	0.65
2nd - 3rd lateral right	-0.74	1.22	1.82	-3.30	0.004	0.22	0.56	0.83	-1.54	0.04	0.001
2nd - 3rd lateral left	-0.27	1.62	4.80	-3.61	0.40	-0.26	0.59	1.25	-1.19	0.02	0.96

+P value from paired t-test to assess change over time
*P value from unpaired t-test to assess whether changes are the same for two groups

transverse offset and linear values. This finding is consistent with previous studies by Hausser, who concluded that the lateral edges of the rugae move forward with the migration of the teeth in extraction cases but felt that the medial ruga points were unaffected.[3,4]

Changes in the medial points of the first rugae were noted in the nonextraction group for both the transverse offset and transverse linear values, suggesting that these points might not be stable references when using the palatal rugae for evaluating tooth movement in a nonextraction group. This observation in adults differs from that of Almeida et al., who found no significant differences between the medial points in children when comparing functional appliances with headgears.[7] The posterior movement of the maxillary anterior teeth does not affect the transverse offset and linear values for the medial and lateral points of the second and third rugae in either extraction or nonextraction groups. This observation may be attributed to a decrease in arch circumference, which primarily affects the anterior part of the palate.

In the extraction group, anteroposterior changes were significantly different for distances between lateral points of the first and second right rugae, between the second and third right rugae, and between the medial points of the second and third right rugae. No statistically significant changes were observed over time in the nonextraction group. The average distances between the lateral first and second right rugae and between the lateral second and third right rugae were significantly different when the two groups were compared. Anatomic differences in the shape, position, and number of rugae between different patients, or even right-sided differences within the same patient, have been demonstrated.[2] Anteroposterior changes over time were different only for the extraction group, suggesting that space closure has some effect on the stability of the rugae. This is especially true of the second rugae. The extraction of two premolars creates space for distal retraction of the maxillary anterior teeth, which apparently changes the anteroposterior values of the lateral and medial points of the second rugae—the one closest to the premolars. The movement of the second rugae has some effect on the anteroposterior values of the first and third rugae. 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. Therefore, these points might serve as stable references when evaluating orthodontic treatment that did not depend on retraction of anterior teeth.

These findings are consistent with those of Schwarze,[9,10,11] who advocated the use of posterior medial ruga points in the evaluation of anteroposterior changes of buccal teeth. However, Schwarze was looking particularly at changes for the first permanent molars. The current investigation also concurs with the findings of Peavy and Kendricks, who concluded that the

rugae were not appreciably altered after orthodontic treatment.[6] Although van der Linden suggested that the lateral ruga points moved in the same direction as the adjacent teeth, he was unable to support this impression statistically because his sample consisted of only six orthodontically treated cases with different types of malocclusions and treatment initiated at various stages of dental development.[12]

The results of this study indicate that the medial and lateral points of the third palatal rugae are stable landmarks for the construction of reference planes in the evaluation of tooth movements in a transverse, linear, and anteroposterior direction, whether patients are treated with or without extraction. The stability of the first and second palatal rugae is limited and dependent on the type of orthodontic treatment, as concluded by previous investigators.[2,6,12] Although there are statistically significant changes within groups, and even some between groups, the mean changes are often too small to be clinically relevant. Changes that involve retraction of anterior teeth limit reliable usage of all except the third palatal rugae as reference points. Tooth movements that would involve transverse expansion might allow reliable use of the palatal rugae as reference points, but requires further investigation.

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