Stability of the palatal rugae as landmarks for analysis of dental casts

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Dental casts are three-dimensional records of malocclusion that have been used most successfully during the diagnosis and treatment planning of orthodontic patients. However, their role in longitudinal studies of growth and development or the analysis of treatment change has been more limited. This stems from the difficulty of identifying stable reference planes that allow superimposition of serial cast data in three planes of space.

In 1981 Scott[1] introduced the reflex metrograph (RMG), a three-dimensional digitizer, to address some of the problems associated with dental cast analysis. Several authors have reported on both the ease of use of the RMG and its reliability in recording the position of dental landmarks from orthodontic casts.[2-8] However, reference landmarks for serial cast analysis must be stable over time with small measurement error.

The palatal rugae may possess unique patient characteristics[9,10] and reasonable stability during growth[11] and may serve as suitable reference points from which to derive the reference planes necessary for longitudinal casts analysis. In a study of the changes occurring in 15 patients treated with extraction of four premolars, Paevy and Kendrick[12] indicated that the lateral ends of the rugae that terminated close to the teeth tended to follow the movement of the teeth in the sagittal plane but not in the transverse plane. The medial terminations of the rugae were not evaluated. Paevy and Kendrick concluded that the rugae were of limited benefit in determining the direction and magnitude of

Abstract

The aims of this study were to determine if the palatal rugae are stable during normal growth, and whether treatment with either headgear or functional appliances affects the position of the rugae. Initial and 15-month recall dental casts of 94 patients enrolled in a study of early Class II treatment were evaluated. The children had been randomly assigned to one of three groups: control (n=34), headgear (n=30), and functional appliance (n=30). Landmarks on the palatal raphe and palatal rugae were recorded using the Reflex Metrograph. A median palatal plane was constructed using the digitized raphe points as reference. Offsets from this plane to the ruga points and transverse and anteroposterior linear distances between ruga points were obtained for all casts. Transverse offsets and linear distances between medial points of the first rugae and the anteroposterior distances between the medial points of the second and third rugae did not show statistically significant changes in all groups. Significant changes were observed for the lateral points of the rugae, particularly in the headgear group. The medial rugae appear to be suitable anatomic points for the construction of stable reference planes for longitudinal cast analysis.

Key Words

Palatal rugae • Stability • Dental cast analysis.

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Table 1
Demographic characteristics of the three patient groups

Groups	n	Males	Females	Mean age years	Range years
Control	34	21	13	9.83	7.33-12.16
Functional	30	16	14	9.87	7.91-11.66
Headgear	30	15	15	9.97	8.08-12.41

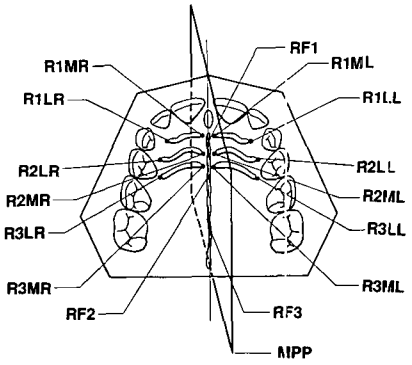

Figure 1
Landmarks marked on the casts: RF1 (point on the median palatal raphe adjacent to the medial point of the right second palatal ruga); RF2 and RF3 (points on the median palatal raphe distally to RF1); RF4 and RF5 (mesial and distal points of the papilla incisiva); and R1MR, R1ML, R1LR, R1LL, R2MR, R2ML, R2LR, R2LL, R3MR, R3ML, R3LR and R3LL (the most medial and lateral end points of the palatal rugae).

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

Group Point	CO x̄	CO sd	FC x̄	FC sd	HG x̄	HG sd
1st Ruga Medial	2.77	0.80	2.70	0.93	3.05	0.94
1st Ruga Lateral	19.07	2.65	19.20	2.24	18.98	2.70
2nd Ruga Medial	3.79	1.42	3.97	2.01	4.72	2.12
2nd Ruga Lateral	19.65	2.45	20.00	2.91	19.25	2.84
3rd Ruga Medial	5.59	2.54	7.40	3.39	5.21	3.39
3rd Ruga Lateral	20.45	3.72	21.08	3.18	19.87	3.40

P=0.28- Multivariate ANOVA

tooth movement but could be of value as an aid in the orientation of a recording device on the midsagittal raphae. In a later study Van der Linden[13] evaluated the anteroposterior (AP) changes between the rugae and the AP relationship between tooth and rugae movement in 65 normally growing children, ages 6 to 16 years, and in six orthodontically treated patients. The maximum mean change between the rugae in the AP plane was 0.41 mm. Larger movements at both the medial and lateral rugae points were noted in the orthodontically treated cases.

Although the palatal rugae have been suggested as potential reference points for longitudinal evaluations, the evaluation of the stability of the rugae over time and the impact of treatment on rugae position has been hampered in previous studies by the small sample sizes, the use of distance measures from rugae to teeth, and the use of reference planes potentially affected by growth and/or treatment. The aims of this study were (1) to determine if the positions of the palatal rugae are stable during normal growth and (2) to evaluate whether treatment with either headgear or functional appliances affects the position of the palatal rugae.

Materials and methods

Subjects

Dental casts from 94 children enrolled in a study of early Class II treatment at the University of North Carolina were evaluated. All children had clinically erupted permanent incisors and first molars, 7 mm or more overjet, and normal development of all teeth. A hand-wrist radiograph was taken to confirm that each child was at least 1 year prior to peak adolescent growth at the time of enrollment. The children were randomly assigned to one of three groups: control (CO), headgear (HG), or functional appliance (FC). The demographic characteristics of the three groups are given in Table 1. Dental casts were obtained at enrollment and at 15 months for the control group and at 15 months or the end of Phase I treatment, whichever occurred first, for the treatment groups.

Children in the headgear group were fitted with a combination headgear. The component force was less than 500 grams per side with the cervical force sufficient only to prevent buccal tipping of the upper molars. The patients were instructed to wear the headgear 12 to 14 hours per day and the force was checked and adjusted at 6-week intervals.

The functional appliance used was a tooth-borne type designed to advance the mandible initially 4 to 5 mm but never past an edge-to-edge incisor position, with minimal vertical opening. Subsequent anterior advancement was achieved with a new appliance if necessary. Patients were instructed to wear the appliances

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

Group	_ CO		_FC		_HG	
Point	x	sd	x	sd	x	sd
1st Ruga Medial	3.18	0.84	3.47	1.37	3.55	1.12
1st Ruga Lateral	19.15	2.7	19.3	2.25	19.09	2.69
2nd Ruga Medial	4.74	1.53	4.62	2.03	5.16	2.01
2nd Ruga Lateral	19.89	2.52	20.29	2.90	19.64	2.84
3rd Ruga Medial	6.07	2.43	7.86	3.36	5.68	3.36
3rd Ruga Lateral	20.77	3.59	21.35	3.11	20.25	3.24

P=0.51- Multivariate ANOVA

Table IV
Mean and standard deviations for initial AP measurements between ruga points (mm) for each group

Group	_ CO		_ FC		_ HG	
Ruga	x	sd	x	sd	x	sd
1st -2nd Medial Right	3.41	1.37	3.95	1.57	3.04	1.44
2nd-3rd Medial Right	4.58	2.16	4.80	1.87	4.60	1.80
1st - 2nd Medial Left	4.46	2.42	4.82	1.63	3.35	1.51
2nd - 3rd Medial Left	4.22	1.89	4.23	1.59	4.68	1.73
1st - 2nd Lateral Right	4.67	2.00	4.41	2.19	4.04	2.99
2nd - 3rd Lateral Right	3.53	2.18	3.41	2.12	4.46	2.65
1st - 2nd Lateral Left	3.74	1.88	3.67	2.15	2.73	1.67
2nd - 3rd Lateral Left	4.15	2.16	4.41	2.18	3.27	2.09

P=0.04- Multivariate ANOVA

approximately 12 to 14 hours per day. Patients were evaluated and the appliance adjusted, if necessary, at 6-week intervals.

Cast analysis

Landmarks (Figure 1) on the palatal raphe and palatal rugae were carefully marked on the upper casts using a 0.3 mm graphite pencil to avoid damage. Both sets of upper casts were positioned side by side when landmarks were marked since the landmarks, especially the ruga points, showed different patterns of shape, size and position between patients. One operator (MAA) marked and another operator (KK) checked the location of the landmarks. If the location of the landmark was doubtful, it was denoted as missing. One medial endpoint of the second ruga, and four endpoints—two medial and two lateral—of the third ruga were excluded.

The landmarks were digitized using the Reflex Metrograph (Ross Instruments Ltd., Slaisbury, Wilts, England) by one operator (MAA). During point location, the operator was "blind" as to the patient's group assignment except in the presence of orthodontic molar bands on the 15-month casts of headgear patients. The two sets of casts were digitized at different times. The mean time spent for recording was 0.2 minutes per point. The digitizing method error for the X-Y-Z coordinates of four points was calculated, using Dahlberg's method,[14] from 12 digitizing replications with at least 2 hours between digitizing sessions. The method error was small in all three dimensions and was lowest for the X-coordinate. The range for X-coordinate digitization error was 0.04 to 0.09 mm, while the Y- and Z-coordinate method errors ranged from 0.10 to 0.22 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 (offsets) 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 AP linear distances between medial and between lateral points of the first, second, and third rugae, were calculated. Changes from the initial to the 15-month (treatment) records were calculated for the transverse offset, transverse linear, and AP linear measures.

Statistical analysis

A multivariate analysis of variance using Wilks' Lambda statistic on the three types of measures (transverse offset, transverse linear, and AP linear) was used to assess whether the three groups of patients differed in ruga position prior to the start of the study. Initial measurements for the three groups are shown in Tables II to IV. There were no statistically significant differences among the three groups in the baseline measures.

Table V
Descriptive statistics for the transverse offset changes of the rugae (mm) for each of the three groups (positive values indicate expansion and negative values indicate constriction).

Point/Group	$\bar{x}$	sd	Max	Min	P+	P*
1st Ruga Medial						
CO	-0.08	0.40	0.95	-0.98	0.24	
FC	0.06	0.40	0.84	-0.68	0.41	0.22
HG	0.15	0.74	2.71	-1.01	0.28	
1st Ruga Lateral						
CO	-0.49	0.94	2.15	-2.43	0.00	
FC	0.18	1.06	4.43	-1.09	0.36	0.00
HG	0.72	1.21	3.02	-2.52	0.00	
2nd Ruga Medial						
CO	0.08	0.51	1.48	-0.68	0.35	
FC	0.16	0.42	0.85	-0.99	0.04	0.46
HG	0.27	0.80	2.07	-2.70	0.07	
2nd Ruga Lateral						
CO	-0.35	0.80	1.20	-1.81	0.02	
FC	0.05	0.84	1.34	-2.34	0.73	0.00
HG	1.10	1.09	3.70	-0.93	0.00	
3rd Ruga Medial						
CO	-0.02	0.47	1.03	-1.10	0.84	
FC	0.08	0.49	1.26	-1.05	0.37	0.21
HG	0.22	0.61	1.43	-1.90	0.06	
3rd Ruga Lateral						
CO	-0.08	0.73	1.41	-2.16	0.55	
FC	0.30	0.92	2.50	-1.78	0.09	0.00
HG	1.47	1.04	4.61	-0.04	0.00	

+P value from paired t-test to assess change over time

*P value from one-way ANOVA to assess whether changes are the same for the three groups

Pairwise contrast P values are given below:

1st Rugae Lateral: CO vs FC P=0.01; CO vs Hg P=0.00; FC vs HG P=0.06

2nd Rugae Lateral: CO vs FC P=0.08; CO vs HG P=0.00; FC vs HG P=0.00

3rd Rugae Lateral: CO vs FC P=0.10; CO vs HG P=0.00; FC vs HG P=0.00

Table VI
Descriptive statistics for the transverse linear changes between bilateral ruga points for each of the three groups (positive values indicate expansion and negative values indicate constriction).

Point/Group	$\bar{x}$	sd	Max	Min	P+	P*
1st Ruga Medial						
CO	0.05	0.64	2.31	-1.15	0.62	
FC	-0.11	0.80	0.90	-3.55	0.48	0.28
HG	0.19	0.72	2.14	-0.86	0.62	
1st Ruga Lateral						
CO	-0.44	0.91	2.18	-2.44	0.01	
FC	0.19	1.08	4.45	-0.99	0.34	0.00
HG	0.76	1.13	3.05	-2.36	0.00	
2nd Ruga Medial						
CO	0.20	0.74	1.85	-1.70	0.13	
FC	0.20	0.61	1.56	-1.22	0.08	0.39
HG	0.41	0.67	2.00	-0.90	0.00	
2nd Ruga Lateral						
CO	-0.27	0.69	1.21	-1.47	0.03	
FC	0.11	0.84	1.59	-2.03	0.50	0.00
HG	1.04	0.99	3.57	-0.94	0.00	
3rd Ruga Medial						
CO	0.04	0.54	1.04	-1.17	0.68	
FC	0.09	0.52	1.31	-0.69	0.35	0.06
HG	0.34	0.51	1.63	-0.63	0.00	
3rd Ruga Lateral						
CO	-0.04	0.73	1.53	-1.93	0.73	
FC	0.47	0.82	2.48	-1.02	0.00	0.00
HG	1.49	0.93	4.41	-0.04	0.00	

+P value from paired t-test to assess change over time

*P value from one-way ANOVA to assess whether changes are the same for the three groups

Pairwise contrast P values are given below:

1st Rugae Lateral: CO vs FC P=0.02; CO vs Hg P=0.00; FC vs HG P=0.03

2nd Rugae Lateral: CO vs FC P=0.08; CO vs HG P=0.00; FC vs HG P=0.00

3rd Rugae Lateral: CO vs FC P=0.02; CO vs HG P=0.00; FC vs HG P=0.00

One-way analysis of variance was used to evaluate whether the average changes in positions of the rugae during the treatment (observation) period were the same for the three groups. Pairwise linear contrasts between the groups were performed if the one-way ANOVA was significant. Paired t-tests were performed within each group to evaluate whether the average change was different from zero. Level of significance was set at 0.01 for all analyses because of the number of comparisons performed.

Results

Means, standard deviations, minimum and maximum values for the transverse offset changes are presented in Table V. The mean change in the offset distances for all measures was quite small, though the range was considerable. The average changes observed over time in each of the three groups were not statistically different from zero for the three medial ruga points (P+ values in Table V represent probability values associated with paired t-tests). The changes observed in the lateral rugae transverse offsets were significant for all rugae in the headgear group and for the first ruga in the control group. In general, the control group showed small but usually positive (expansion) mean changes; the functional appliance group showed

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

Point/Group	$\bar{x}$	sd	Max	Min	P+	P*
1st - 2nd Right Rugae						
CO	0.09	0.89	3.09	-2.45	0.54	
FC	-0.07	1.07	2.35	-2.39	0.71	0.07
HG	0.52	1.09	4.11	-2.05	0.01	
2nd - 3rd Right Rugae						
CO	-0.27	1.05	1.07	-3.25	0.14	
FC	0.24	1.28	3.24	-3.39	0.30	0.04
HG	0.44	1.06	2.93	-1.98	0.03	
1st - 2nd Left Rugae						
CO	0.07	1.29	2.66	-2.96	0.74	
FC	-0.06	1.25	2.95	-2.62	0.79	0.14
HG	0.58	1.29	4.83	-1.84	0.02	
2nd - 3rd Left Rugae						
CO	-0.02	0.99	1.83	-4.06	0.89	
FC	0.30	1.02	3.76	-1.38	0.12	0.72
HG	0.31	1.18	3.18	-2.67	0.17	

+P value from paired t-test to assess change over time

*P value from one-way ANOVA to assess whether changes are the same for the three groups

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

Point/Group	$\bar{x}$	sd	Max	Min	P+	P*
1st -2nd Right Rugae						
CO	0.06	1.88	3.91	-4.97	0.85	
FC	0.70	1.74	4.64	-2.40	0.04	0.14
HG	0.95	1.84	4.88	-2.95	0.01	
2nd - 3rd Right Rugae						
CO	0.17	1.72	4.01	-3.06	0.56	
FC	0.47	1.77	3.61	-3.25	0.16	0.72
HG	0.13	1.80	2.85	-4.63	0.69	
1st - 2nd Left Rugae						
CO	0.16	1.74	3.71	-5.22	0.60	
FC	0.24	1.79	4.77	-3.68	0.48	0.19
HG	0.89	1.58	4.28	-2.56	0.00	
2nd - 3rd Left Rugae						
CO	-0.11	1.54	2.95	-4.06	0.67	
FC	0.94	1.61	3.52	-2.53	0.00	0.05
HG	0.40	1.82	5.58	-2.14	0.25	

+P value from paired t-test to assess change over time

*P value from one-way ANOVA to assess whether changes are the same for the three groups

small and always negative (constriction) mean changes; and the headgear group showed larger and always negative mean changes. The lateral rugae offset changes were significantly different among the three groups (P* <0.01), while the medial rugae changes were not (P* >0.01).

Table VI shows descriptive statistics for the transverse linear changes. The results were similar to those for the offset values. The medial points of the first rugae were stable in the transverse plane regardless of treatment group or kind of measurement (offset or linear distances).

Anteroposteriorly, the average changes in the distance between medial ruga points were also small. Only the headgear group showed a tendency for an increase between the medial points of the rugae (Table VII). The average changes between the lateral ruga points were similar in magnitude to those between the medial terminations. The average lateral distance between the first and second rugae of both sides in the headgear group and between the second and third left rugae in the functional group was significantly increased (Table VIII). However, there were no significant differences among the groups for either the medial or the lateral AP distance changes (Tables VII and VIII).

Discussion

The location and recording of the points were easily performed with the Reflex Metrograph. Minimum training was needed to achieve results with low errors. However, eyestrain was a problem and rest intervals were required. The mean time spent for recording, 0.2 minutes per point, was similar to Richmond[5] who reported 0.18 minutes per point. The error of recording the points in this study was low and similar to the findings of Takada et al.,[7] Richmond and Jones,[2] and Lee.[8]

Our results suggest that the transverse offsets and distances between medial ruga points were generally stable, particularly for the first rugae. There were no statistically significant changes within any of the groups nor any differences among the groups for the first rugae. Functional and headgear appliances did not alter the transverse measurements of the medial ruga points during the observation time of our study. Although there were significant changes between the medial points of the second and third rugae in the headgear group, the average change was less than 0.5 mm. On average, the changes between medial points of the first rugae were less than 0.2 mm for all groups. This is in agreement

with the findings of Moyers[11] and Van der Linden.[13]

The lateral ruga points appear less stable. The transverse offsets and linear distances between lateral ruga points showed statistically significant changes not only in the treatment groups but also in the control group. These results concur with those of Moyers et al.,[11] who reported changes for distances between lateral ruga points in normally growing children, and with Van der Linden[13] and Paevy and Kendrick[12] who observed the influence of orthodontic treatment on the positions of the lateral ruga points. In our study, on average, the control group exhibited a constriction tendency of the lateral ruga points, while the headgear group showed an amount of expansion greater than that observed in the functional group. The larger average expansion observed in the headgear group may be related to posterior tooth movement that was occurring during this time interval.

Anteroposterior distances between ruga points were stable in the control group (greatest mean change= 0.27 mm), which supports the findings of Moyers et al.[11] However, statistically significant changes were observed for some AP distances within the treatment groups, but the differences in the changes among the groups were not large enough to be detected as significantly different. AP distances between medial points of the second and third rugae seem less influenced by treatment.

The vertical changes of the palatal rugae were not determined in this study. Moyers et al.[11] reported that the distances between the functional occlusal plane and the ruga points increased over time, particularly the distances from the medial points of the third rugae. However, whether this change is due to changes in the rugae or to occlusal plane variation is not possible to establish.

The medial ruga points appear to be suitable anatomic points for use as reference landmarks for longitudinal cast analysis in the transverse and anteroposterior planes. The medial points did not show statistically significant changes during the short observation period in this study.

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