The Online ANGLE ORTHODONTIST
An International Journal of Orthodontics and Dentofacial Orthopedics
78th Anniversary 1930-2008

TABLE OF CONTENTS

---

doi: 10.2319/0003-3219(2007)077[0457:MEAAAT]2.0.CO;2
***The Angle Orthodontist:* Vol. 77, No. 3, pp. 457–462.**

Masticatory Exercise as an Adjunctive Treatment for Hyperdivergent Patients

Laurie R. Parks;[a] Peter H. Buschang;[b] Richard A. Alexander;[b] Paul Dechow;[b] Paul Emile Rossouw[c]

ABSTRACT

Objective: This retrospective study was designed to evaluate the morphologic effects of masticatory muscle exercise as an adjunctive therapy for hyperdivergent patients treated with fixed orthodontic appliances.

Materials and Methods: Three samples of 50 subjects were selected, including one sample treated with orthodontics combined with exercise, one sample treated with orthodontics only, and an untreated control sample. Subjects were matched on the basis of age, sex, mandibular plane angle (MPA), treatment duration, and treatment rendered. Patients in the treated exercise sample were instructed to clench their teeth together as hard as possible for 15 seconds and to repeat this process at least four times for a total of one minute; this one-minute exercise was to be performed as often as possible throughout the day. Morphologic data was derived from pre- and posttreatment lateral cephalograms.

Results: Exercise with orthodontics produced significant ($P < .05$) increases in overbite compared to orthodontics alone. However, changes in vertical facial morphology were not significantly different between the two treated samples. Relative to untreated controls, both treated samples showed significantly greater increases in the MPA (S-N to Go-Me), Y-axis, and the lower to total facial height ratio; the treated samples also showed significantly less true forward mandibular rotation than the untreated controls.

Conclusion: Short-term clenching exercises performed daily are insufficient as an adjunct to traditional orthodontic treatment for correcting or controlling the vertical dimension.

KEY WORDS: Hyperdivergence, Cephalometrics, Exercise, Fixed orthodontic treatment.

Accepted: July 2006. Submitted: March 2006

INTRODUCTION Return to TOC

Hyperdivergent patients typically exhibit short posterior facial heights, long anterior facial heights, large mandibular plane angles (MPA), large gonial angles and greater than average lower to upper anterior facial height ratios.[1–6] The dentition of hyperdivergent patients is likely to be over-erupted, with excess dentoalveolar height.[4,5,7,8] The problems associated with hyperdivergent patients are further exasperated because orthodontic treatment can be extrusive.[9–12] Control of molar extrusion and mandibular rotation is essential because skeletal open bite patients are characterized by a backward and downward rotation of the mandible,[1–5] which must be addressed to correct any vertical dysmorphology and open bite. The various treatment modalities currently available, including high-pull headgear,[12–16] posterior bite-blocks,[17–21] and vertical pull chin-cups[3,22– 25] have shown limited success in controlling the vertical dimension.

In addition to excess vertical facial morphology, hyperdivergent patients have smaller and weaker masticatory muscles,[26–28] and their impaired muscle function has been directly associated with their craniofacial skeletal dysmorphology.[27,29,30] Weak orofacial muscles imply weak occlusal forces, which might create an environment that allows the molars to supra erupt as the mandible rotates downwards and backwards.

If weak masticatory muscles are associated with hyperdivergence, then strengthening masticatory muscles could help in the treatment of hyperdivergent patients. Studies have demonstrated strengthening of the masticatory muscle with various exercises.[30–34] Increases in masticatory muscle strength have been produced with daily exercise regimens lasting only five minutes per day[34] and over periods of less than one month.[30,33]

If weak masticatory musculature is a factor in the development of hyperdivergent morphology, then muscle strengthening in growing patients might be expected to produce a more favorable skeletal pattern and occlusion. Exercises have produced reductions in the anterior to total facial height ratio, reductions in the gonial angle, and increases in true mandibular rotation.[16,35–37] However, most of the exercise regimens producing clinically relevant morphologic changes required considerable amounts of time each day and high levels of patient compliance. For example, Spyropoulos[35] required subjects to chew a hard gum for a minimum of 45 minutes per day over 21 months; Ingervall and Bitsanis[36] instructed patients to chew a tough pine tree resin for two hours per day for one year, and Bakke and Siersback-Nielson[37] required subjects to chew hard exercise gum for two and a half hours per day for one year.

Given that there is a relationship between masticatory muscle strength and facial morphology, and that it is possible to strengthen masticatory muscles with limited amounts of exercise, the present study was performed to investigate the effectiveness of a practical and minimally invasive regimen of masticatory muscle exercises as an adjunct to a traditional orthodontic treatment philosophy.

MATERIALS AND METHODS Return to TOC

Treated samples

Two independently treated samples were selected from the private offices of two orthodontists, Dr Richard A. Alexander and Dr Dean Jensen. Patients were selected based on the following criteria:

- Chronologic age ranging from 9–18 years
- Late mixed to permanent dentition
- Good quality pre- and posttreatment cephalograms
- Vertical growth tendency—defined as a greater than Average MPA (MP-SN > 35°) based on age and Sex-specific norms provided by Riolo et al[38]
- anterior edge-to-edge or open bite relationship (treated samples only).

Samples were matched on the basis of starting age, sex, MPA, treatment duration, and treatment rendered (Table 1). The treated samples (ORTHO-ALONE and ORTHO-EXERCISE) each included 50 patients (14 male, 36 female) treated with fixed orthodontic appliances (Alexander prescription), utilizing similar mechanics and similar regimens of elastic wear (CII, CIII, anterior box as needed).

One treated sample (ORTHO-EXERCISE) followed an exercise regimen which involved clenching teeth together (in maximum intercuspation) as hard as possible for 15 seconds and repeating the process at least four times for a total of one minute. The orthodontist recommended repetition of the one-minute exercise as often as possible throughout the day. The orthodontist also recommended chewing sugarless gum as much as possible. Compliance was based on written instructions documented in the progress notes on the chart. Reminders were given throughout the treatment period.

Untreated control sample

The untreated control sample consists of 50 (14 male, 36 female) untreated individuals who were followed longitudinally by the Human Growth Research Center in Montreal, Montreal, Canada. The untreated control sample was matched to both treated samples on the basis of age, sex, MPA, and time interval (analogous to treatment duration of the treated groups).

Cephalometric methods

Lateral cephalometric radiographs were taken before the initiation of treatment and after the completion of treatment. All cephalograms were traced by the same examiner using Dentofacial Planner Plus® software. Cephalometric magnification was corrected based on the source-to-film distances used for each of the three samples.

Fifteen cephalometric landmarks (Figure 1) were digitized on each radiograph. Treatment effects were evaluated based on 12 measurements (Table 2) computed by the Dentofacial Planner Plus software. Intra-examiner reliability was assessed by replicate measurements of 20 radiographs. Differences between the replicates showed no significant systematic errors; method errors ($(\Sigma\ differences^2/2n)^{1/2}$) ranged between 0.36° and 0.52° for the angular measures and between 0.34 mm and 0.48 mm for the linear measures.

Mandibular regional superimpositions were performed to evaluate true mandibular rotation. A mandibular reference plane (MRP) was defined by two fiduciary points located anterior and posterior to the mandibular corpus and below the occlusal plane (Figure 1). Superimpositions were performed as described by Björk and Skeiller.[39] The two fiduciary points defining the MRP on the pretreatment tracing were transferred to the posttreatment tracing after superimposition. True mandibular rotation was defined as the angular change between the sella-nasion plane and the MRP.

Intrusion of the maxillary dentition was measured as the perpendicular distances from the first molar (mesial cusp tip) and incisal tip to the palatal plane. Intrusion of the mandibular dentition was measured as the distance from the first molar (mesial cusp tip) and incisal tip to the MRP.

Statistical methods

Based on the skewness and kurtosis statistics, all measures were normally distributed. Analyses of variance (ANOVA) were used to determine group differences. Post hoc analyses of group differences were performed using Scheffe's tests. A 0.05 level was used to determine statistical significance.

RESULTS Return to TOC

Initially, the three samples showed no significant differences in the MPA, gonial angle, lower to total facial height ratio, or posterior to anterior facial height ratio (Table 3). The two treated samples showed no pretreatment differences. The palatal plane angle (PPA) and overbite were significantly larger in the untreated control sample than in both of the treated samples. The Y-axis was significantly larger in the untreated control sample than the ORTHO-ALONE sample treated with orthodontics alone.

There were no significant differences in the changes of MPA, gonial angle, Y-axis, PPA, lower to total facial height ratio, or posterior to anterior facial height ratio between the treated samples (Table 4). The increase in overbite was significantly greater in the ORTHO-EXERCISE sample than in the other two samples, with the untreated controls showing the smallest increase in overbite.

Comparisons of the treated and untreated samples showed clear and consistent treatment effects (Table 4). The MPA in the untreated controls sample decreased significantly in relation to the treated samples, both of which showed increases. The decrease in the gonial angle was significantly greater in the untreated control sample than in the ORTHO-ALONE sample. The lower to total facial height ratio increased in all three samples, but the increase was significantly less in the untreated control sample than in the treated samples.

The movements of the upper incisor relative to the palatal plane were not significantly different among the three samples (Table 5). However, the movement of the upper molar in relation to the palatal plane was significantly greater in the ORTHO-EXERCISE sample than in the untreated control sample. The increase in distance from the lower incisor to the MRP in the untreated control sample was significantly less than that of the treated samples. The untreated control sample also showed significantly less movement of the lower molar relative to the MRP and significantly more true mandibular rotation than the treated samples. The untreated control sample underwent 1.5° of true forward rotation, whereas the ORTHO-EXERCISE and the ORTHO-ALONE samples showed no statistically significant changes over time.

DISCUSSION Return to TOC

Orthodontics along with clenching exercises apparently produces a greater increase in overbite than orthodontics alone. The slight reduction in the gonial angle and the increase in posterior to anterior facial height ratio in the ORTHO-EXERCISE sample could have contributed to the correction of the open bite. There clearly is no single factor that explains the changes in overbite, suggesting that a combination of morphologic and dentoalveolar changes must have been responsible for the overbite correction observed.

Importantly, the majority of morphologic measurements showed no statistically significant exercise effect. Based on the previous literature, the treated experimental sample was expected to show significant improvements in vertical morphologic characteristics. Decreases in the anterior to posterior facial height ratio ranging from 0.2[16] to 1.25,[36] decreases in gonial angle ranging from 1.3[16] to 3.1 degrees, [35] and anterior mandibular rotation ranging from 2.2[16] to 6.0[37] degrees have been previously reported after variable periods of exercise. While type II errors associated with age differences and technical errors cannot be ruled out, the sample sizes and, more importantly, the small magnitudes of differences between the two treated samples suggest that there really was no exercise effect.

The lack of exercise effect could be explained by compliance and the amount of exercise performed. Of the two, compliance is probably most important because exercise can only be effective if the subject cooperates consistently. In the present study, compliance in the treated experimental sample was not objectively measured. Although reminders were given by the orthodontist at each appointment, compliance was based on the patients' self-report. Bite marks on soft bite-blocks[40] or wafers[16] have been previously used to measure compliance, which was not possible in this retrospective study. Related to compliance, the extent of exercise performed each day may not have been sufficient. The studies showing the greatest morphologic effects required between 45 minutes and 2½ hours of exercise per day.[35–37] Subjects performing less exercise demonstrate more limited morphologic effects.[16,40]

Both of the treated samples showed increases in the vertical dimension that were significantly greater than those of the untreated controls. This indicates a negative orthodontic treatment effect, previously described as an increase of the MPA, vertical movement of pogonion, and extrusion of mandibular molars.[9–12] In this study, the treated samples showed an increase in the MPA, whereas the MPA in the untreated control sample decreased. Importantly, the treated groups showed more extrusion of the teeth, especially the mandibular teeth, than the untreated controls. While greater extrusion might be expected and desirable for correcting the anterior relationships, posterior extrusion of teeth associated with treatment is not desirable.

Based on the findings of the present study, exercise should not be discarded as a treatment option for hyperdivergent patients. Because it potentially addresses the etiology of the malocclusion, masticatory exercise could be an effective adjunct of treatment. In fact, an effective exercise regimen could provide a rationale for early treatment of vertical problems before they fully develop. Muscle strengthening holds great promise as an adjunctive therapy. Spyropoulos,[35] for example, found that the exercise produced greater improvement in skeletal pattern and anterior open bite than chin cup therapy. Studies investigating the effects of high-pull headgear[12,14,15] have not shown the amounts of mandibular rotation possible with masticatory muscle exercise alone. Furthermore, treatment modalities involving cumbersome or uncomfortable appliances such as headgear, bite-blocks, or chin-cups, could produce noncompliant patients and excess expense for the patient and orthodontist.

CONCLUSIONS Return to TOC

a. Masticatory muscle exercise performed during the treatment of hyperdivergent patients produced greater increases in overbite than treatment alone.

b. Masticatory muscle exercise had no significant effect on the majority of vertical morphologic measurements.

c. Hyperdivergent subjects treated with orthodontic fixed appliances showed an increase in vertical measurements relative to untreated controls.

REFERENCES Return to TOC

1. Sassouni V. A classification of skeletal types. *Am J Orthod.* 1969; 55:109–123.

2. Bell WH. Correction of skeletal type of anterior open bite. *J Oral Surg.* 1971; 29:706–714.

3. Pearson L. Vertical control in treatment of patients having backward-rotational growth tendencies. *Angle Orthod.* 1978; 48:132–140.

4. Cangialosi T. Skeletal morphologic features of anterior open bite. *Am J Orthod.* 1984; 85:28–36.

5. Fields H, Proffit W, Nixon W, Phillips C, Stanek E. Facial pattern differences in long-faced children and adults. *Am J Orthod.* 1984; 85:217–223.

6. Nanda S. Patterns of vertical growth in the face. *Am J Orthod Dentofacial Orthop.* 1988; 93:103–116.

7. Haralabakis NB, Yiagtzis SC, Toutountzakis NM. Cephalometric characteristics of open bite in adults: a three-dimensional cephalometric evaluation. *Int J Adult Orthod Orthognath Surg.* 1994; 9:223–231.

8. Tsang WM, Cheung LK, Samman N. The effects of isometric exercise on maximum voluntary bite forces and jaw muscle strength and endurance. *J Oral Rehab.* 2001; 28:909–917.

9. Phan XL, Schneider BJ, Sadowsky C, BeGole EA. Effects of orthodontic treatment on mandibular rotation and displacement in Angle Class II division 1 malocclusions. *Angle Orthod.* 2004; 74:174–183.

10. Taner-Sarisoy L, Darendeliler N. The influence of extraction orthodontic treatment on craniofacial structures: evaluation according to two different factors. *Am J Orthod Dentofacial Orthop.* 1999; 115:508–514.

11. Mair AD, Hunter WS. Mandibular growth direction with conventional Class II nonextraction treatment. *Am J Orthod Dentofacial Orthop.* 1992; 101:543–549.

12. Baumrind S, Molthen R, West EE, Miller DM. Mandibular plane changes during maxillary retraction. *Am J Orthod.* 1978; 74:32–40.

13. Watson W. A computerized appraisal of the high-pull face bow. *Am J Orthod.* 1972; 62:561–579.

14. Caldwell SF, Hymas TA, Timm TA. Maxillary traction splint: a cephalometric evaluation. *Am J Orthod.* 1984; 85:376–384.

15. Firouz M, Zernik J, Nanda R. Dental and orthopedic effects of high-pull headgear in treatment of Class II division 1 malocclusion. *Am J Orthod Dentofacial Orthop.* 1992; 102:197–205.

16. Tran M. *The Adjunctive Treatment Effects of Light Masticatory Muscle Training on Skeletal Hyperdivergent Morphology: A Pilot Study* [master's thesis]. Dallas, Tex: Baylor College of Dentistry; 2001.

17. Dellinger EL. A clinical assessment of the Active Vertical Corrector—a nonsurgical alternative for skeletal open bite treatment. *Am J Orthod.* 1986; 89:428–436.

18. Karla V, Burstone C, Nanda R. Effects of a fixed magnetic appliance on the dentofacial complex. *Am J Orthod Dentofacial Orthop.* 1989; 95:467–478.

19. Kiliaridis S, Egermark I, Thilander B. Anterior open bite treatment with magnets. *Eur J Orthod.* 1990; 12:447–457.

20. Kuster R, Ingervall B. The effect of treatment of skeletal open bite with two types of bite-blocks. *Eur J Orthod.* 1992; 14:489–499.

21. Iscan HN, Sarisoy L. Comparison of the effects of passive posterior bite-blocks with different construction bites on the craniofacial and dentoalveolar structures. *Am J Orthod Dentofacial Orthop.* 1997; 112:171–178.

22. Pearson L. Vertical control in fully-banded orthodontic treatment. *Angle Orthod.* 1986; 56:205–224.

23. Pearson L. Case report KP. Treatment of a severe open bite excessive vertical pattern with an eclectic non-surgical approach. *Angle Orthod.* 1991; 61:71–76.

24. Sankey W, Buschang P, English J, Owen A. Early treatment of vertical skeletal dysplasia: the hyperdivergent phenotype. *Am J Orthod Dentofacial Orthop.* 2000; 118:317–327.

25. Iscan HN, Dincer M, Gultan A, Meral O, Taner-Sarisoy L. Effects of vertical chincap therapy on the mandibular morphology in open-bite patients. *Am J Orthod Dentofacial Orthop.* 2002; 122:506–511.

26. Ringqvist M. Isometric bite force and its relation to dimensions of the facial skeleton. *Acta Odontol Scand.* 1973; 31:35–42.

27. Ingervall B, Helkimo E. Masticatory muscle force and facial morphology in man. *Arch Oral Biol.* 1978; 23:203–206.

28. Proffit W, Fields H, Nixon W. Occlusal forces in normal and long-face adults. *J Dent Res.* 1983; 62:566–571.

29. Corruccini RS. An epidemiologic transition in dental occlusion in world populations. *Am J Orthod.* 1984; 86:419–426.

30. Kiliaridis S, Johansson A, Haraldson T, Omar R, Carlsson G. Craniofacial morphology, occlusal traits, and bite force in persons with advanced occlusal tooth wear. *Am J Orthod Dentofacial Orthop.* 1995; 107:286–292.

31. Brekhus PJ, Armstrong WD, Simon WJ. Stimulation of the muscles of mastication. *J Dent Res.* 1941; 20:87–92.

32. Yurkstas A. The effect of masticatory exercise on the maximum bite force tolerance of individual teeth. *J Dent Res.* 1953; 32:322–327.

33. Tzakis MG, Kiliaridis S, Carlsson GE. Effect of a fatigue test and chewing training on masticatory muscles. *J Oral Rehab.* 1994; 21:33–45.

34. Thompson DJ, Throckmorton GS, Buschang PH. The effects of isometric exercise on maximum voluntary bite forces and jaw muscle strength and endurance. *J Oral Rehab.* 2001; 28:909–917.

35. Spyropoulos M. An early approach for the interception of skeletal open bites: a preliminary report. *J Pedo.* 1985; 9:200–209.

36. Ingervall B, Bitsanis E. A pilot study of the effect of masticatory muscles training on facial growth in long-face children. *Eur J Orthod.* 1987; 9:15–23.

37. Bakke M, Siersbaek-Nielsen S. Training of mandibular elevator muscles in subjects with anterior open bite. *Eur J Orthod.* 1990; 2:502

38. Riolo M, Moyers RE, McNamara J. *An Atlas of Craniofacial Growth. Monograph No. 2, Craniofacial Growth Series, Center for Human Growth and Development*. Ann Arbor, Mich: The University of Michigan; 1974.

39. Björk A, Skieller V. Normal and abnormal growth of the mandible: a synthesis of longitudinal cephalometric implant studies over a period of 25 years. *Eur J Orthod.* 1983; 5:1–46.

40. Insoft RM, Sanderson IR, Walker WA. The nonsurgical treatment of a Class II open bite malocclusion. *Am J Orthod Dentofacial Orthop.* 1996; 110:598–605.

TABLES Return to TOC

Table 1. Demographic Characteristics of the Two Treated and Control Samples

Variable	ORTHO-EXERCISE	ORTHO-ALONE	Untreated Controls
Sex	36 F, 14 M	36 F, 14 M	36 F, 14 M
Starting age, years	12.4 ± 1.6	12.3 ± 1.5	12.3 ± 1.5
Duration, years	2.8 ± 1.0	2.7 ± 1.1	2.7 ± 1.3
Treatments rendered[a]	10 RPE; 10 Ext; 12 HG	10 RPE; 10 Ext; 12 HG	N/A

[a] RPE, Rapid Palatal Expansion; Ext, Extraction; HG, Head Gear.

Table 2. Cephalometric Measurements, Definitions and Method Errors

Measurement	Unit	Definition	Method Error
MPA	deg	SN to Go-Me	0.52
Gonial angle	deg	Ar-Go-Me	0.40
Y-axis	deg	N-S-Me	0.38
PPA	deg	SN to ANS-PNS	0.36
LFH:TFH	%	ANS-Me: N-Me Lower face height to total face height ratio	ANS-Me 0.34 N-Me 0.48
PFH:AFH	%	S-Go; N-Me Posterior face height to anterior face height ratio	S-Go 0.44 N-Me 0.48
Overbite	mm	Lower to upper incisal edge, evaluated parallel to Down's occlusal plane	N/A
U1t–PP	mm	Upper incisal edge to palatal plane	N/A
U6t–PP	mm	Mesial cusp of upper molar to palatal plane	N/A
L1t–MRP	mm	Lower incisal edge to mandibular reference plane	N/A
L6t–MRP	mm	Mesial cusp of lower molar to mandibular reference plane	N/A
SN to MRP	deg	True rotation	N/A

Table 3. Pretreatment Dimensions of Vertical Morphology. With Group Differences Determined ANOVAs Followed by Scheffe's Post Hoc Tests

		ORTHO-EXERCISE		ORTHO-ALONE		Untreated Controls		Group Differences[b]		
Variable[a]	Unit	Mean	SD	Mean	SD	Mean	SD	1 vs 2	1 vs 3	2 vs 3
MPA	deg	40.3	4.8	38.8	4.1	40.0	3.4	NS	NS	NS
Gonial angle	deg	133.2	4.8	132.3	4.7	133.1	3.7	NS	NS	NS
Y-axis	deg	71.6	4.1	70.6	3.8	72.9	2.7	NS	NS	.001
PPA	deg	7.1	3.3	7.2	3.5	9.4	3.4	NS	.001	.002
LFH:TFH	%	57.8	2.2	57.6	2.2	57.1	2.2	NS	NS	NS
PFH:AFH	%	60.1	3.6	60.8	2.9	60.1	2.4	NS	NS	NS
Overbite*	mm	−0.9	1.2	−0.6	1.3	3.9	1.8	NS	.000	.000

[a] MPA indicates mandibular plane angle; PPA, palatal plane angle; LFH:TFH, lower facial height to total facial height ratio; PFH:AFH, posterior facial height to anterior facial height ratio.
[b] NS indicates not significant.
* Negative value indicates an open bite relationship; positive value indicates an overbite relationship.

Table 4. Vertical Morphologic Changes, With Group Differences Determined by ANOVAs Followed by Scheffe's Post Hoc Tests

		ORTHO-EXERCISE		ORTHO-ALONE		Untreated Controls		Group Differences[b]		
Variable[a]	Unit	Mean	SD	Mean	SD	Mean	SD	1 vs 2	1 vs 3	2 vs 3
MPA	deg	0.4	2.8	0.7	2.3	−0.8	2.2	NS	.018	.004
Gonial angle	deg	−1.2	2.5	−0.7	2.2	−1.8	1.7	NS	NS	.008
Y-axis	deg	0.7	1.5	0.8	1.7	0.03	1.4	NS	.031	.015
PPA	deg	−0.1	2.0	0.2	2.2	0.1	1.2	NS	NS	NS
LFH:TFH	%	0.9	1.1	0.7	1.7	0.04	0.8	NS	.001	.008
PFH:AFH	%	0.2	2.5	0.3	2.4	0.9	1.7	NS	NS	NS
Overbite*	mm	1.5	1.5	0.7	1.2	0.1	2.0	.031	.000	NS

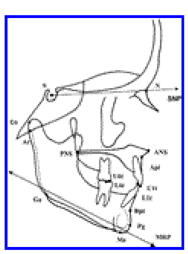
[a] MPA indicates mandibular plane angle; PPA, palatal plane angle; LFH:TFH, lower facial height to total facial height ratio; PFH:AFH, posterior facial height to anterior facial height ratio.
[b] NS indicates not significant.
* Positive value indicates an increase in the overbite; negative value indicates an opening of the bite.

Table 5. Vertical Dental Changes and True Rotation, With Group Differences Determined by ANOVAs Followed by Scheffe's Post Hoc Tests

		ORTHO-EXERCISE		ORTHO-ALONE		Untreated Controls		Group Differences[b]		
Variable[a]	Unit	Mean	SD	Mean	SD	Mean	SD	1 vs 2	1 vs 3	2 vs 3
U1t–PP	mm	1.9	1.6	2.2	1.9	1.8	1.6	NS	NS	NS
U6t–PP	mm	2.1	1.6	1.6	1.9	1.2	1.6	NS	.006	NS
L1t–MRP	mm	2.8	2.0	2.7	2.2	1.6	1.3	NS	.024	.006
L6t–MRP	mm	2.3	1.8	2.6	1.8	2.0	2.4	NS	.003	.007
True rotation*	deg	−0.04	2.5	0.3	2.4	−1.5	2.6	NS	.005	.000

[a] U1t–PP indicates upper incisal edge to palatal plane; U6t–PP, mesial cusp of upper molar to palatal plane; L1t–MRP, lower incisal edge to mandibular reference plane; L6t–MRP, mesial cusp of lower molar to mandibular reference plane.
[b] NS indicates not significant.
* Positive value indicates backward rotation; negative value indicates forward rotation.

FIGURES Return to TOC



Click on thumbnail for full-sized image.

Figure 1. Reference lines and landmarks: S, sella; N, nasion; ANS, anterior nasal spine; Apt, A-point; U1t, upper incisal edge; L1t, lower incisal edge; Bpt, B-point; Pg, pogonion; Me, menton; Go, gonion; Ar, articulare; Co, condylion; PNS, posterior nasal spine; U6t, upper molar mesial cusp tip; L6t, lower molar mesial cusp tip; SNP, sella-nasion reference plane; MRP, mandibular reference plane

[a]Resident, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex

[b]Professor, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex

[c]Professor and Chair, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex

Corresponding author: Dr Peter H. Buschang, Department of Orthodontics, Baylor College of Dentistry, 3302 Gaston Avenue, Dallas, TX 75124 (E-mail: phbuschang@tambcd.edu)