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Original Article

MESIAL MOVEMENT OF MAXILLARY FIRST MOLARS AND VERTICAL DIMENSIONAL CHANGES IN ORTHODONTIC EXTRACTION TREATMENT FOR PATIENTS WITH DIFFERENT FACIAL MORPHOLOGY

Abdurahman Alwadei[1], Farhan Alwadei[2], Ali Alfarhan[3], Madhur Upadhyay[4], Saleh Alwadei[5]

[1]Assistant Professor, Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.

[2&5]Assistant Professor, Department of Preventive Dental Sciences, College of Dentistry, Prince Sattam Bin Abdulaziz University, Al-Kharj 11942, Saudi Arabia.

[3]Teaching assistant, Department of Restorative Dental Sciences, College of Dentistry, King Khalid University, Abha, Saudi Arabia.

[4]Associate Professor, Division of Orthodontics (L-7060), Department of Craniofacial Sciences, University of Connecticut Health, 263 Farmington Avenue, Farmington, CT 06030, USA.

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ABSTRACT

Objectives: Primarily, to compare anchorage loss and changes in mandibular plane (MP) angle, overbite, and amount of horizontal, vertical, and angular movements of maxillary incisors in groups of hypodivergent, hyperdivergent, and normodivergent patients. Secondarily, to analyze the relationship between those factors.

Methods: Pre- and post-treatment cephalograms of 89 patients treated with extraction of four bicuspids or two maxillary bicuspids were analyzed. The sample was divided into three groups based on their facial pattern measured by SN-MP angle (hypodivergent: $< 27^0$, hyperdivergent: $>38^0$, and normodivergent: 27^0-38^0). Linear and angular measurements included the distances of U1 tip and U6 mesial height of contour to Y-axis (i.e., line perpendicular to the X-axis, passing through Sella turcica), distance of U1 tip to Sella on X-axis, overbite, angulation of U1 to palatal plane, and SN-MP and ANB angles. Inferential statistics included one-way ANOVA, Chi-square test, independent t-test, and Pearson's correlation coefficients.

Results: Facial morphology did not primarily affect anchorage loss, because other factors such as crowding, severity of Class II molar relationship, and extraction modality played more impactful role ($P< 0.01$). Change in mandibular plane angle was neither influenced by, nor correlated with, initial facial morphology or anchorage loss ($P> 0.05$). Positive change in overbite was significantly correlated with facial pattern, incisor extrusion and retroclination ($r= 0.30$, 0.44, and -0.35, respectively, $P< 0.01$).

Conclusion: Anchorage loss in extraction orthodontic treatment is not influenced primarily by initial facial morphology. Anchorage loss is not significantly associated with MP angle reduction. Change in overbite can be achieved through incisor extrusion and retroclination.

Key Words: Facial pattern, Anchorage loss, Extraction effects, vertical dimension.

Corresponding author:

Abdurahman Alwadei
King Saud University, College of Dentistry
Department of Pediatric Dentistry and Orthodontics
Building #23, 1st Floor, Room 17
P.O. Box 60169, Riyadh 11545
Kingdom of Saudi Arabia
Phone: (+966) 531937982
Email: aalwadei@ksu.edu.sa

INTRODUCTION:

The vertical facial growth pattern of the face is established early in life and maintained throughout growth in both hypodivergent and hyperdivergent individuals. [1] The anatomy of jaw bones is significantly affected by interference with facial growth and muscles.[2] Most skeletal and dental characteristics commonly seen in patients with markedly increased or decreased vertical growth patterns were initially described by Bjork in his landmark longitudinal study in 1969.[3] Bjork and others reported skeletal and dental characteristics of hyperdivergent patients including distal backward condylar inclination, short ramus, straight mandibular canal, antegonial notching, obtuse gonial angle, steep mandibular plane (most important), thin and long symphysis, acute intermolar and interincisal angulation, divergent occlusal planes, anteriorly tipped-up palatal plane, over-erupted maxillary molars, long lower anterior facial height, and short posterior facial height.[4] On the other hand, skeletal and dental characteristics of hypodivergent growth pattern have been described to be contrasting to those seen in hyperdivergent patients.[3]

Specific considerations while planning orthodontic treatment must be considered regarding mandibular muscles and vertical dimension including extrusive forces, extraction, muscular anchorage, and retention.[5] Since orthodontic extraction treatment is indicated in specific clinical situations, anchorage preservation becomes a major concern especially when correcting severe crowding, excessive overjet, and bimaxillary protrusion. [6] Anchorage loss is a multifactorial response that could be affected primarily or secondarily by several biological or mechanical factors. [6] The rate of tooth movement is influenced by cortical bone thickness.[7] Hypodivergent patients have thicker cortical bone and stronger mandibular musculature when compared to hyperdivergent patients.[7] The concept of muscular anchorage has also been thought to play a role in anchorage.[8] Anchorage potentials in these two groups of patients may be different given their contrasting morphological characteristics. Extraction versus non-extraction approach in treatment of hypo- and hyper-divergent patients have been reported to either avoid excessive vertical closure or to increase the overbite, respectively.[9-16] Although a recent systematic review reported insignificant impact of orthodontic extraction treatment on the vertical dimension, it remains a debatable issue due to conflicting empirical evidence along with clinicians' preferred methods of treatment based on strongly held beliefs.[13,17] More importantly, comparison of anchorage loss in patients with different facial patterns has not received the same attention in the orthodontic literature. Rather, more focus has been placed on aspects related to various types of appliances and biomechanical strategies, biological factors, amount of crowding, as well as age and sex. [18-23]

It is necessary to understand the morphology of hyperdivergent and hypodivergent patients to appropriately recognize the full scale of underlying etiology (i.e., skeletal, dental, esthetic, or functional) and to reach a sound diagnosis and execute proper management of orthodontic and/or orthognathic cases. In the orthodontic literature, the impact of facial morphology on anchorage loss in orthodontic extraction of premolars is not yet fully understood. Furthermore, the impact of orthodontic extraction of premolars on skeletal vertical dimension and changes in overbite remains a controversial issue with lack of consensus regarding two main points. First, does pre-treatment facial morphology, as a primary determinant, justify extraction versus non-extraction approach? Secondly, does mesialization of the posterior dentition after extraction result in closure of the bite? Therefore, the primary aim of this study is to compare anchorage loss and changes in mandibular plane (MP) angle, overbite, and amount of horizontal, vertical, and angular movements of maxillary incisors following extraction of premolars (four bicuspids or two maxillary first bicuspids) in groups of hypodivergent, hyperdivergent, and normodivergent patients. A secondary aim is to analyze the relationship between initial facial pattern, anchorage loss, and changes in MP angle, overbite and maxillary incisor's angulation and position.

MATERIALS AND METHODS:

Ethical approval for this study (IRB no: 15-040-1) was provided by the Ethical Committee at The University of Connecticut Health, Farmington, on 21 August 2014. The sample consisted of patients who were treated at the orthodontic clinic at the University of Connecticut Health. We included patients with Class I and/or Class II skeletal pattern (ANB ≥ 0) and fully erupted permanent teeth (except third molars) who received an extraction treatment of two maxillary first bicuspids or all four first bicuspids, using bonded fixed metal appliances, i.e., preadjusted edgewise 0.022" slot, MBT prescription. Exclusion criteria included: (1) medical conditions that could affect tooth movement (2) missing permanent teeth (except third molars), (3) orthognathic surgery cases, and (4) use of skeletal anchorage devices.

A power analysis was conducted using G*Power 3.1.7 software to determine a sufficient sample size using the large limit of the effect size and produced a sample size estimate of 28 participants per group with a conventional alpha level (p=0 .05) and desired power ($1 – \beta$) of 0.90. The sample was divided into 3 groups according to vertical facial patterns based on the Sella-Nasion to MP (SN-MP) angle, i.e., hyperdivergent SN-MP >38^0, normdivergent $27^0 \leq$ SN-MP $\leq 38^0$, and hypodivergent SN-MP < 27^0. A total of 950 medical records were reviewed, and 89 met the inclusion criteria and were divided into hypodivergent (n= 29), normodivergent (n= 30), and hyperdivergent facial types (n= 30). Pre- and post-treatment lateral cephalograms were manually traced and superimposed to measure anchorage loss and vertical changes. Cephalograms tracing and superimposition was done by one operator using acetate paper and 0.5mm black and red mechanical pencils for pre-treatment for post-treatment cephalograms, respectively. Digital caliper was used to validate printing magnification accuracy and to register linear measurements, while a manual protractor was used for angular measurements. [24]

The superimposition of lateral cephalograms at the two time points was done as described by Davoody et al. [18] To quantify the anchorage loss by measuring the mesial movement of maxillary molars (U6), [18] maxillary superimpositions were performed. The superimpositions were done on internal cortication of the maxilla and an X-axis which was drawn by connecting the anterior nasal spine (ANS) and posterior nasal spine (PNS). A Y-axis was derived by drawing a line perpendicular to the X-axis, passing through Sella turcica. After superimposition on the internal cortication of the maxilla, the X-Y coordinate system was transferred to T2 cephalogram from T1 lateral cephalogram. The horizontal changes of maxillary first molars and central incisor (U1) were measured using the Y axis as reference plane. Similarly, vertical incisor changes were measured from the X-axis. The change in inclination of maxillary incisors was measured by extending a line along the long axis of the incisor to the palatal plane (ANS-PNS) and the interior angle was measured to determine changes in incisor angulation (Figure 1). Vertical maxillary incisor changes were measured from the X-axis (Figure 1). The skeletal and dental changes (SN-MP, ANB, overbite and maxillary first molars and incisor) were determined by subtracting the T1 values from T2 (T2-T1). Tracing of 10 lateral cephalograms was performed by two assessors (S.A, F.A) which were analyzed for inter-rater reliability After 15 days, each operator retraced the same ten sets of cephalograms to determine the intra-rater reliability. All cephalograms used for this study were then traced and superimposed by the same assessor (S.A). Using patients' records, we recorded demographic data, Angle's dental malocclusions, and amount of crowding. Crowding was calculated according to an arch space analysis method reported by Proffit et al. (2018). [9]

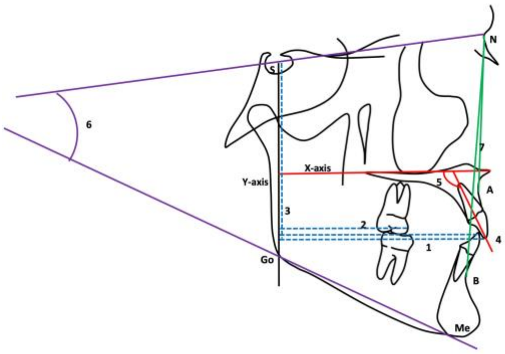

Figure 1. Lateral cephalometric linear and angular measurements

<u>Maxillary regional superimposition</u>

1- Distance of U 1 Tip to Y at T1, and T2.

2- Distance of U 6 mesial height of contour to Y at T1 and T2.

3- Distance of U 1 Tip to Sella on X at T1, and T2.

4- Overbite (Distance from lower incisor to upper incisor to X at T1 and T2)

5- Angulation of U 1 to palatal plane

<u>Other angular measurements</u>

6- Mandibular plane to Sella-Nasion angle (MP-SN).

7- ANB angle.

STATISTICAL ANALYSIS:

Data analysis was performed using SPSS Statistics for Windows (version 28.0; IBM, Armonk, NY). The intraclass correlation coefficient was used to test reliability for tracing. The Shapiro Wilk test for normality was conducted and the following variables were found not to be normally distributed: pre- and post-treatment SN-MP angle, ANB angle, and overbite. Nonetheless, Kruskal Wallis and one-way ANOVA tests were performed to determine whether there was a significant change from T1 to T2. Given the obtained sample size and the fact that both non-parametric and parametric statistical tests showed similar results, one-way ANOVA results are reported. [25] Correlation among various variables was calculated using Pearson's correlation coefficient (r). Statistical significance was noted at P value < 0.05. When evaluating the strength of correlation, the following classification was used: strong if ρ is > 0.7 and ≤ 1.0, moderate if ρ is ≥ 0.4 and ≤ 0.7, and weak if ρ is > 0.2 and < 0.4.

RESULTS:

The age of patients ranged from 11 to 18 years, with a mean age of 13.3 years. We used one-way ANOVA test (for treatment duration, age, and crowding) and Chi-square test (for gender, Angle's classification of dental malocclusion, severity of Angle's CL II malocclusion, and extraction pattern) to determine if there were statistically significant differences between the three groups in relation to baseline demographic and pre-treatment characteristics (Table 1). No differences were found in relation to age, gender, treatment duration, and severity of Angle's Class II molar relationship. However, there were statistically significant baseline differences in the amount of crowding (P= 0.005 and 0.001), Angle's dental malocclusions classification (Class I, II and III), and type of extraction treatment. Interestingly, most notable differences were related to hypodivergent group. In other words, hypodivergent patients presented with the least amount of crowding and number of Class I dental malocclusion and received the least number of four bicuspids extraction treatment. On the other hand, they had the highest number of Class II dental malocclusion and received the highest number of maxillary bicuspids extraction treatment (P = 0.005 and 0.000, respectively)(Table 1).

Table 1. Baseline demographics and pre-treatment characteristics

Variables	Groups			P Value
	Hyperdivergent	Hypodivergent	Normodivergent	
Gender (females)	18 (60%)	16 (55.2%)	19 (63.3%)	0.910
Age (years)	13.4±1.95	12.7±1.77	13.4±2.60	0.166
Treatment duration (months)	35.93±7.80	37.24±8.14	35.17±9.26	0.724
Crowding (millimeters)				
Maxillary	5.65±3.16	1.56±3.20	3.711±3.26	***0.005****
Mandibular	4.61±4.26	0. 88±3.26	2.80±3.34	***0.001****
Angle's classification of dental malocclusion				
Class I	14 (46.7%)	3 (10.3%)	12 (40.0%)	***0.005****
Class II	13 (43.3%)	26 (89.7%)	16 (53.4%)	
Class III	3 (10.0%)	0	2 (6.6%)	
Severity of Angle's CL II malocclusion				
Full cusp (100%)	4	10	9	0.343
End-on (50%)	9	16	7	
Extraction pattern				
Two upper bicuspids	9	23	16	***0.000****
Four bicuspids	21	6	14	
**** Significant P values***				

Intraclass and interclass correlations showed strong correlations (r= 0.92 and 0.86, respectively) indicating reliability. Table 2 shows descriptive and inferential statistics of cephalometric angular and linear measurements. Of seven measurements related to post- to pre-treatment average differences, mesial movement of maxillary first molars (i.e., anchorage loss) and overbite showed statistically significant differences between the three groups (P < .05). Anchorage loss was highest in hypodivergent patients (4.24±1.16mm) compared to hyperdivergent and normal patients (3.52±0.81mm and 3.36±1.28mm, respectively). Change in overbite was lowest in hyperdivergent patients (-0.58±1.48mm) compared to hypodivergent and normal patients (-1.96±2.24mm and -1.90±1.70mm, respectively). (Table 2) To further investigate the differences between the groups' means, post-hoc Tukey's test for multiple comparisons was performed (Table 3). The mean changes in anchorage loss showed statistically significant differences between hypodivergent group and both hyperdivergent and Normodivergent groups (P= 0.006). The mean changes in overbite showed statistically significant differences between hyperdivergent group and both hypodivergent and Normodivergent groups (P= 0.006)(Table 3).

Table 2. **Descriptive statistics and tests of between-subjects' effects for one-way ANOVA**

Variable	Groups	N	Pre-treatment (T1)		Post-treatment (T2)		Changes from T1 to T2				
									95% CI		
			Mean	SD	Mean	SD	Mean	SD	Lower Bound	Upper Bound	P-value
MP-SN	Hyperdivergent	30	45.86	2.44	46.07	2.92	0.20	1.13	-0.22	0.62	0.058
	Hypodivergent	29	26.20	1.17	25.76	1.88	-0.45	1.50	-1.02	0.12	
	Normodivergent	30	35.06	2.28	34.45	3.14	-0.66	1.63	-1.26	-0.06	
	Total	89	35.82	8.31	35.53	8.77	-0.31	1.47	-0.61	0.002	
ANB	Hyperdivergent	30	6.06	2.23	5.07	2.12	-1.00	0.79	-1.29	-0.71	0.411
	Hypodivergent	29	5.37	2.49	4.41	2.06	-0.97	1.12	-1.39	-0.54	
	Normodivergent	30	4.80	2.12	4.15	1.95	-0.69	1.01	-1.06	-0.32	
	Total	89	5.42	2.32	4.54	2.06	-0.88	0.98	-1.09	-0.68	
U6 mesial movement	Hyperdivergent	30	28.61	4.02	32.12	4.09	3.52	0.81	3.21	3.82	**0.006 ***
	Hypodivergent	29	36.91	4.85	41.16	4.89	4.24	1.16	3.80	4.68	
	Normodivergent	30	33.20	4.61	36.57	4.59	3.36	1.28	2.89	3.83	
	Total	89	32.86	5.61	36.57	5.81	3.69	1.16	3.45	3.94	
U1 horizontal/ distal movement	Hyperdivergent	30	54.85	6.21	50.39	5.11	-4.46	2.82	-5.51	-3.41	0.146
	Hypodivergent	29	65.42	7.02	61.31	5.92	-4.11	2.18	-4.93	-3.28	
	Normodivergent	30	60.35	5.63	57.03	5.57	-3.22	2.51	-4.14	-2.30	
	Total	89	60.15	6.59	56.18	7.10	-3.92	2.55	-4.45	-3.38	
U1 vertical movement	Hyperdivergent	30	74.67	4.10	75.44	4.15	0.77	2.03	0.01	1.53	0.095
	Hypodivergent	29	71.88	6.00	71.75	5.93	0.13	2.31	-0.75	1.01	
	Normodivergent	30	74.11	3.34	73.79	2.87	-0.38	1.78	-1.03	0.27	
	Total	89	73.57	4.70	73.68	4.68	0.17	2.08	-0.26	0.60	
U1-PP angulation	Hyperdivergent	30	114.37	6.32	107.70	4.85	-6.67	7.68	-9.53	-3.80	0.262
	Hypodivergent	29	117.03	10.29	113.79	6.26	-3.24	11.15	-7.48	1.00	
	Normodivergent	30	116.40	7.39	113.08	5.99	-2.89	10.33	-6.68	0.90	
	Total	89	115.92	8.13	111.50	6.29	-4.26	9.86	-6.33	-2.20	
Overbite	Hyperdivergent	30	2.88	1.33	2.30	0.73	-0.58	1.48	-1.13	-0.03	**0.006***
	Hypodivergent	29	4.37	2.37	2.41	0.53	-1.96	2.24	-2.81	-1.11	
	Normodivergent	30	3.99	2.14	2.13	0.78	-1.90	1.70	-2.53	-1.28	
	Total	89	3.74	2.07	2.28	0.69	-1.48	1.91	-1.89	-1.08	
**** Significant P values***											

Table 3. Multiple comparisons of post hoc test (Tukey HSD)

Variables (Changes from T1 to T2)			Mean Difference (I-J)	Std. Error	P Value	95% CI	
						Lower Bound	Upper Bound
MP-SN	Hyperdivergent	Hypodivergent	.648	.374	.260	-.265	1.562
		Normodivergent	.861	.368	.065	-.037	1.760
	Hypodivergent	Hyperdivergent	-.648	.374	.260	-1.561	.265
		Normodivergent	.213	.371	1.000	-.693	1.119
	Normodivergent	Hyperdivergent	-.861	.368	.065	-1.760	.037
		Hypodivergent	-.213	.371	1.000	-1.119	.693
ANB	Hyperdivergent	Hypodivergent	-.034	.255	1.000	-.657	.588
		Normodivergent	-.306	.251	.674	-.918	.305
	Hypodivergent	Hyperdivergent	.034	.255	1.000	-.588	.657
		Normodivergent	-.271	.253	.855	-.889	.345
	Normodivergent	Hyperdivergent	.306	.251	.674	-.305	.918
		Hypodivergent	.271	.253	.855	-.345	.889
U6 mesial movement	Hyperdivergent	Hypodivergent	-.727*	.287	.040	-1.429	-.025
		Normodivergent	.160	.283	1.000	-.530	.850
	Hypodivergent	Hyperdivergent	**.727***	.287	**.040***	.025	1.429
		Normodivergent	**.887***	.285	**.008***	.191	1.584
	Normodivergent	Hyperdivergent	-.160	.283	1.000	-.850	.530
		Hypodivergent	-.887*	.285	.008	-1.583	-.191
U1 horizontal/distal movement	Hyperdivergent	Hypodivergent	-.354	.656	1.000	-1.956	1.249
		Normodivergent	-1.241	.646	.173	-2.817	.335
	Hypodivergent	Hyperdivergent	.354	.656	1.000	-1.249	1.956
		Normodivergent	-.88734	.651	.530	-2.477	.703
	Normodivergent	Hyperdivergent	1.241	.646	.173	-.335	2.817
		Hypodivergent	.887	.651	.530	-.703	2.477
U1 vertical movement	Hyperdivergent	Hypodivergent	.640	.531	.696	-.658	1.939
		Normodivergent	1.149	.523	.092	-.128	2.427
	Hypodivergent	Hyperdivergent	-.640	.532	.696	-1.939	.658
		Normodivergent	.509	.528	1.000	-.779	1.798
	Normodivergent	Hyperdivergent	-1.149	.523	.092	-2.427	.128
		Hypodivergent	-.509	.528	1.000	-1.798	.779
U1-PP angulation	Hyperdivergent	Hypodivergent	-3.425	2.558	.552	-9.669	2.819
		Normodivergent	-3.779	2.515	.410	-9.920	2.361
	Hypodivergent	Hyperdivergent	3.425	2.558	.552	-2.819	9.669
		Normodivergent	-.354	2.537	1.000	-6.549	5.840
	Normodivergent	Hyperdivergent	3.779	2.515	.410	-2.361	9.920
		Hypodivergent	.354	2.537	1.000	-5.839	6.549
Overbite	Hyperdivergent	Hypodivergent	**1.381***	.475	**.014***	.221	2.541
		Normodivergent	**1.322***	.467	**.017***	.182	2.463
	Hypodivergent	Hyperdivergent	-1.381*	.475	.014	-2.541	-.221
		Normodivergent	-.058	.471	1.000	-1.209	1.092
	Normodivergent	Hyperdivergent	-1.322*	.467	.017	-2.463	-.182
		Hypodivergent	.058	.471	1.000	-1.092	1.209

**** Significant P values***

Using Pearson's correlation coefficients, no significant correlations were found between anchorage loss, changes in SN-MP angle and overbite ($P > .05$). However, pretreatment facial morphology showed significant weak correlations with anchorage loss ($r= - 0.26$, $P= 0.013$), change in overbite ($r= 0.30$, $P= 0.005$), and change in SN-MP angle ($r= - 0.24$, $P= 0.025$). Change in incisor angulation showed negative week correlation with change in overbite ($r= - 0.36$, $P= 0.000$). Finally, incisor extrusion was moderately correlated with change in overbite ($r= 0.44$, $P < 0.01$). (Table 3).

Table 4. Pearson correlation coefficients between dependent and independent variables (n=89)

Bivariate correlation	Coefficient of correlation	P value
Anchorage loss and changes in SN-MP	r= - 0.20	0.060
Anchorage loss and overbite	r= - 0.19	0.073
Overbite and changes in SN-MP	r= 0.17	0.116
Anchorage loss and pre-treatment facial morphology	r= - 0.26	**0.013***
Overbite and pre-treatment morphology	r= 0.30	**0.005***
Overbite and change in incisor angulation	r= - 0.36	**<0.001***
Overbite and change in incisor vertical position	r= 0.44	**<0.001***
Pre-treatment morphology and changes in SN-MP	r= 0.24	**0.025***
**** Significant P values***		

Independent t-test was conducted to compare changes in MP angle and overbite between different extractions patterns, regardless of facial morphology. Out of 89 patients, 48 patients received two upper bicuspids extraction and 41 patients received four first bicuspids extraction. Regarding change in MP angle, there was no significant difference between the maxillary first bicuspids group ($M= -0.17$, $SD= 1.61$) and four first bicuspids group ($M= -0.43$, $SD= 1.28$), $t(0.83) = 87$, $p = 0.407$. However, there was a significant difference in change in overbite between the maxillary first bicuspids group ($M= -1.98$, $SD= 2.01$) and four first bicuspids group ($M= -0.86$, $SD= 1.64$), $t(-2.83) = 87$, $p = 0.006$

Table 5. Independent t-test for comparing changes in mandibular plane angle and overbite between different extractions patterns (n=89)

Dependent Variable	Extraction pattern	Mean (SD)	t	df	Mean difference	P value
Change in MP-SN angle (T2-T1)	Two upper bicuspids (n=48)	-0.17 (1.61)	0.83	87	2.60	0.407
	Four bicuspids (n=41)	-0.43 (1.28)				
Change in overbite (T2-T1)	Two upper bicuspids (n=48)	-1.98 (2.01)	-2.83	87	-1.11	***0.006****
	Four bicuspids (n=41)	-0.86 (1.64)				
**** Significant P value, equal variance is assumed***						

DISCUSSION:

Anchorage control is an important consideration when planning to close spaces in orthodontic extraction cases, especially when maximum anchorage is required. Despite the potential differences in anchorage loss among patients with different facial patterns who received orthodontic extraction treatment, exploration such as the one described in this study is underexposed. Taken at face value, the results indicate that anchorage loss is significantly influenced by and associated with facial patterns. In that, one-way ANOVA and post-hoc tests show greater anchorage loss among hypodivergent patients compared to hyperdivergent and normodivergent patients ($p = 0.040$ and 0.008, respectively as displayed in Table 2). Furthermore, anchorage loss was significantly (and negatively) associated with pre-treatment facial morphology represented by SN-MP angle ($r = -0.263$, $P = 0.013$) (Table 4). However, further consideration and analysis of pretreatment factors indicate that the amount of crowding, severity of Class II molar relationship, and extraction treatment approach played more impactful role. These factors are explained more in-depth in the following text.

Concerning crowding, hypodivergent group presented with the least amount of crowding, leaving more spaces to be closed after leveling and alignment phase. This observation was further supported by significant negative association between anchorage loss and amount of crowding. Furthermore, a significantly higher number of hypodivergent patients presented with class II end on molar relationship of which majority of them were treated with extraction of two maxillary premolars. Thus, maxillary 1st molars had to be moved mesially more to achieve full cusp class II molar relationship (Table I). Despite our effort to include hypodivergent patients who received extraction treatment of four premolars (i.e., by reviewing around 1000 medical records), we could not find such patients to represent the hypodivergent group. Interestingly, our results show that majority of patients in the hyperdivergent group (70%, n= 21/30) received extraction of four first bicuspids, as opposed to only 20% (n= 6/29) of patients in the hypodivergent group. This observation can be attributed to the possibility that orthodontists, based on deep-rooted beliefs or empirical findings corroborating the wedge hypothesis, may tend to avoid extraction of four premolars in hypodivergent patients out of concern that it will further increase the overbite., and may opt for four bicuspids extraction approach in hyperdivergent patients to increase the overbite. [9,26] Therefore, caution must be taken when interpreting our results.

Klapper and colleagues examined anchorage loss with two maxillary bicuspids extraction treatment in hypodivergent and hyperdivergent patients, using cervical headgear and class II elastics, and found insignificant differences.[27] When compared to our findings, they reported less anchorage loss among hypodivergent patients but higher anchorage loss among hyperdivergent patients. Klapper et. al. applied different mechanics and did not provide data regarding pretreatment characteristics (e.g., skeletal relationship, crowding, molar relationship) or patients' compliance with headgear wear. Kim et al. (2005) studied anchorage loss in hyperdivergent patients with Class I dental malocclusion who received extraction of maxillary 1st or 2nd bicuspids. [13] They reported higher anchorage loss among 2nd premolars extraction group compared to 1st premolars extraction group (3.84 mm $\pm$ 1.22 and 2.72 $\pm$1.41 mm, respectively). In comparison to our findings, specifically within hyperdivergent patients, they reported less anchorage loss. However, there were noteworthy differences related to pretreatment dental malocclusion, extraction pattern, treatment mechanics and lack of comparison group(s). Heo et al. compared the amount of anchorage loss between en masse and two-step retraction approaches, with more hypodivergent patients in the two-step retraction approach.[20] They reported insignificant difference in anchorage loss between hypodivergent and normodivergent patients (1.88$\pm$.64 mm, 2.03$\pm$.77mm, respectively). In agreement with our findings in the normodivergent group, Chen et al. reported 3.2 $\pm$1.1mm mesial movements of maxillary first molar in their normodivergent patients treated with 2nd premolar extraction. [28]

A critical appraisal of the evidence, including this study, regarding inconsistent amounts of anchorage loss could be attributed to several reasons; for example, the complexity and individual variations of patients, considerable differences in pretreatment characteristics within and between studies including severity of crowding, molar relationship, vertical skeletal pattern, and other orofacial and dental characteristics, and different treatment modalities used in each study. These factors may result in wide range of individual variations in tooth movement. Thus, direct comparison is difficult and careful interpretation is warranted.

Control of vertical dimension in hyperdivergent and hypodivergent patients is essential but often difficult to attain and maintain. In support of numerous studies, [5, 13, 27, 29-30] our findings indicate insignificant correlations between anchorage loss and changes in MP angle and overbite. This finding disagrees with the wedge hypothesis which postulates that mesialization of posterior teeth away from the hinge axis can lead to closure of mandibular plane angle. [26] Our finding was further confirmed by dividing the total sample based on extraction pattern, regardless of facial morphology, where 41 patients received four bicuspid extraction and 48 patients received two upper bicuspids extraction. Such an additional classification of the sample was made to test if mesialization of upper and lower posterior teeth leads to reduction of mandibular plane angle. There was no significant difference between the two groups (Table 5).

While facial morphology appears to significantly correlate with change in overbite, its impact may be clinically insignificant when determining extraction versus non-extraction treatment, given the magnitude of overbite changes noted in hyperdivergent and hypodivergent patients (Tables 2 and 3). Furthermore, change in overbite was not significantly associated with horizontal movements of maxillary 1st molar or maxillary incisors (Table 4). In fact, change in overbite, regardless of facial morphology, was significantly higher among patients who received extraction of maxillary first bicuspids only compared to those who received extraction of four bicuspids (Table 5). More importantly, clinically meaningful associations were found between change in overbite and incisor extrusion and angulation change (Table 5). This observation corroborates the "drawbridge effect" which assumes the bite is deepened with extractions of first premolars by retroclination and extrusion of incisors during retraction. [31]

Disagreement between different studies regarding the relationship between facial morphology and control of vertical dimension could be because changes in skeletal and dental vertical dimensions involve an interplay of various biological and/or biomechanical factors that are difficult to dissect, especially as they occur simultaneously in a complex system during orthodontic treatment. Some of these potentially influential factors analyzed in this study include facial morphology, extraction treatment approach as well as vertical incisor extrusion and changes in incisor angulation during incisor retraction. It is important to acknowledge that some factors might hold greater potential impact on the vertical dimension than others.

This retrospective study has several limitations and are prioritized next according to their impact on the interpretations of this study findings and its implications. Firstly, the inability to locate the needed number of patients who received four bicuspids extraction to be included in the hypodivergent patient group. Therefore, results obtained from comparison between the groups must be interpreted with great caution given the differences in anchorage requirements. Secondly, detailed account of treatment specific biomechanics throughout treatment and facial growth could not be accounted for given the retrospective nature of this study, in which their impact could have been significant in contributing to anchorage loss. Thirdly, vertical extrusion of molars was not measured, and it should have been considered as it may counterbalance any undesirable decrease or increase in overbite observed during extraction treatment among hyperdivergent and hypodivergent patients. These limitations present an opportunity for further research by conducting a well-controlled prospective study that address the main limitations mentioned above. Although it will be difficult to conduct, it would minimize confounding factors and methodological biases, because such methodological variability within and among similar studies remains an issue that complicates generating meaningful comparison across studies.

We conclude by extrapolating our findings to a clinical context, taking into consideration the limitations of this study. It may not be justifiable to reason orthodontic extraction treatment in hyperdivergent and hypodivergent patients based primarily, and more so solely, on facial morphology. This study further highlights the complexity associated with clinical decision-making regarding anchorage requirements as well as selection and/or prioritization of extraction versus non-extraction modality among hyperdivergent and hypodivergent patients. Therefore, we recommend clinicians to consider factors such as individual variations in growth and development including bone maturation, severity of skeletal and dental malocclusion, amount of crowding, treatment modality, treatment mechanics, and patient compliance.

CONCLUSION

Pre-treatment facial morphology does not seem to have a primary impact on horizontal anchorage loss in extraction orthodontic treatment. Instead, other factors such as patient age, crowding, severity of pretreatment Class II molar relationship, and extraction treatment approach should be considered when anchorage preservation is required. In disagreement with the wedge hypothesis, anchorage loss does not significantly reduce the mandibular plane angle. However, in agreement with the basis of drawbridge effect, positive changes in overbite can be achieved through incisor extrusion and retroclination.

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DECLARATION OF INTERESTS

The authors have no conflict of interest.

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