Original Article

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Comparison treatment effects of twin block appliance between hyperdivergent and normovergent patients

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Objective: A retrospective study to compare skeletal and dentoalveolar changes between hyperdivergent and normovergent Class II division 1 Thai patients treated with twin block appliance.
Materials and Methods: Pretreatment and posttreatment lateral cephalometric radiographs of 17 hyperdivergent [9 boys, 8 girls] and 26 normovergent [16 boys, 10 girls] Class II division 1 Thai subjects treated with twin block appliance were analysed. The subjects were divided into 2 different vertical growth patterns, hyperdivergent and normovergent groups by SN-MP angle. Cephalometric analysis and Pancherz analysis were performed and the treatment effects between 2 groups were compared by using an independent t-test.
Results: Pretreatment SN-MP of hyperdivergent group was 38.98 ± 1.84°, while it was 30.06 ± 2.71° in normovergent group. According to MU analysis, normovergent group showed a statistically significant greater improvement in sagittal skeletal changes (increased SNB, decreased ANB, improved AF-BF and increased Pg to N perpend) when compared to the hyperdivergent group. There was no significant difference of vertical skeletal changes between the two groups except the mandibular angle which showed a slight increase after twin block treatment in the normovergent group. According to Pancherz analysis, the skeletal/ dental contribution for overjet correction was 36.6 /63.4 percent and molar correction was 47.5 /52.5 percent in hyperdivergent group. While the skeletal/ dental contribution for overjet correction in normovergent group was 52.1 /47.9 percent and molar correction was 58.7 /41.3 percent. However, skeletal change is not significant between hyperdivergent and normovergent group.
Conclusions: Normovergent patients responded to the twin block appliance more favorably than hyperdivergent patients according to MU analysis but skeletal change in term of mandibular advancement was similar.

Keywords: Class II division 1 patients, hyperdivergent, normovergent, treatment effects, twin block appliance, vertical growth pattern

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Introduction

Malocclusion may result from the misalignment of the teeth and/or a discrepancy in the relationship between the maxilla and mandible. Class II division 1 malocclusion is usually characterized by proclined maxillary incisors, increased overjet, and maxillary arch constriction. [1] Various treatment approaches are available for the management of Class II malocclusion. Functional appliances are commonly used for the management of mandibular retrusion in growing subjects. The twin block appliance, which was originally developed by Clark, is one of the most popular functional appliances used in Thailand because of its uncomplicated design and ease of use.

The twin block appliance is a tooth-borne functional appliance, which consists of two separate upper and lower removable acrylic components which position the mandible forward

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through interlocking occlusal bite block at a 70° angle in occlusion. [2] The independent units facilitate speech and mastication and are proved to be associated with good patient compliance. [3] In vertical dimension, the bite blocks of the appliance can be trimmed to facilitate the eruption of the lower posterior teeth in patients with a deep bite and a deep curve of spee. Conversely, in patients with open bite tendency and/or increased lower facial height, the bite blocks can be left to prevent the eruption of the posterior teeth. [3, 4]

Functional appliance works by changing the activity of the various jaw muscle groups that influence function and position of the mandible. [5] By altering sagittal and vertical mandibular position, pressure is generated due to stretching of muscles and surrounding soft tissues. The resultant force is transmitted to the underlying dental and skeletal tissues and brings about orthodontic and orthopaedics changes. [6] Some animal studies have shown that when mandible was brought in a forward position, an increase in cellular activity at the condylar head as well as an increase in mandibular length had occurred. [4, 7-11] The treatment effects and stability of early Class II treatment with any functional appliance have faced much controversy. Lund and Sandler [12] showed that molar relationships were corrected by means of restraint in the eruption of the upper molars, lower molar eruption and forward growth or repositioning of the mandible. Statistically significant increases in mandibular length were observed in the study of Mill et al. [3], Illing et al. [13], Toth and McNamara[14], Jena et al. [15] and Giuntini et al. [16] In addition, Jena et al. [15] concluded that twin block appliance was effective in overjet and molar correction in Class II division 1 malocclusion patients. On the other hand, there were some randomized controlled clinical trial studies [17, 18] that noted early treatment with functional appliances was not clinically effective. Besides, hyperdivergent patients are supposed to show unfavorable treatment effects owing to vertical growth pattern.[19-21]

To our knowledge, no clinical studies have been conducted in Thai patients to investigate the clinical effects of functional appliances in Class II division 1 malocclusion patients. In addition, there are no study that evaluate the changes of the treatment with twin block appliance by distinguishing vertical growth pattern of the patients. The purpose of this study was to compare skeletal and dentoalveolar changes between hyperdivergent and normovergent Class II division 1 Thai patients treated with twin block appliance.

Subjects and Methods

Ethical statement

This study was approved by the Committee in the Ethics of Research in Human Dentistry and Pharmacy of Mahidol University, Institutional Review Board (Protocol No. MU-DT/PY-IRB 2016/036.2808).

Treatment protocol

The design of the twin block appliance used in this study was modified from the conventional twin block appliance developed by Clark [2, 22, 23] (as shown in Figure 1). Lower bite blocks have acrylic incisor capping to minimize proclination of lower

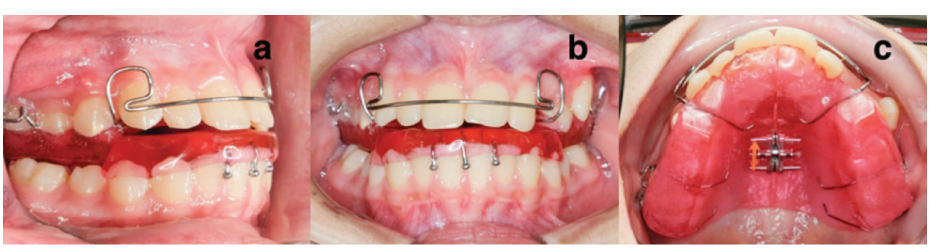

Fig. 1 Intraoral photographs with twin block appliance: a. Lateral view, b. Frontal view, c. Occlusal view

anterior teeth and additional ball clasps between interproximal of lower anterior teeth were used to improve retention. [18] For the upper appliances, Adam's clasps were used instead of delta clasps.

Sample selection

The subjects in this study included 43 Class II Thai patients treated with twin block appliance. The criteria for case selection were as follows:

1. Skeletal Class II malocclusion with mandibular deficiency (ANB ≥ 4 degrees)
2. Angle's Class II division 1 with at least half cusp of class II molar relationship
3. Excessive overjet 5 mm. or greater
4. No craniofacial deformity
5. No history of orthodontic treatment and no permanent tooth extraction
6. Good patient compliance (appliance was repeatedly broken, the patient refused to wear the appliance, these patients were classified as noncompliant that would be excluded from this study)
7. Good quality of all cephalometric radiographs used in this study

Cephalometric analysis

Pretreatment (T1) and posttreatment after twin block (T2) lateral cephalometric radiographs were used in this study. They were traced by one investigator with 0.3 mm 2H pencil on matte acetate paper. When there were bilateral structures, the reference points were placed in average between them. A cephalometric protractor was used to measure all variables. The points and planes used in this cephalometric analysis were shown in Figure 2.

Thirty cephalometric variables were generated to compare between 2 groups as follows:

Skeletal (Antero-posterior relationship)		
1. SNA	2. SNB	3. ANB
4. A to N perpend (mm) to FH plane	5. Pg to N perpend (mm) to FH plane	6. AF-BF (mm)
7. AO-BO (mm) related to functional occlusal plane	8. Pg-NB (mm)	9. Co-A (mm)
10. Co-Gn (mm)	11. Mand-max difference (CoGn-CoA) (mm)	

Skeletal (Vertical relationship)		
1. SN-MP	2. MP-PP	
3. Mandibular angle (refers to the angle between mandibular plane and Ar to posterior border of ramus of mandible)		
4. PFH/AFH (S to Go / N to Me)	5. Facial index (N-ANS' / ANS'Me) * * ANS': point of intersection between palatal plane and N to Me	

Dentoalveolar		
1. U1-NA (Upper central incisor to NA)	2. U1-NA (mm)	3. U1-SN
4. L1-NB (Lower central incisor to NB)	5. L1-NB (mm)	6. L1-MP
7. U1-L1 (interincisal angle)	8. Overjet (mm)	9. Overbite (mm)
10. Anterior maxillary alveolar height (Ant.max.alv.ht.; mm): tip of U1 to palatal plane		
11. Posterior maxillary alveolar height (Post.max.alv.ht.; mm): the mesio-buccal cusps of upper first molars to palatal plane		

Soft tissue profile		
1. Nasolabial angle (refers to the angle between nose and upper lip)		
2. H-angle (NB to UL-PG)	3. Lower lip to E-plane (mm)	

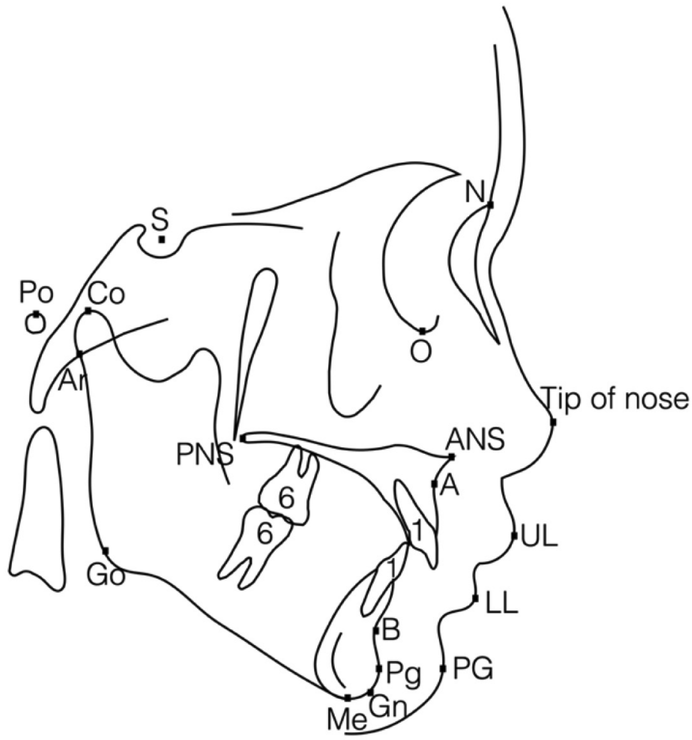

Fig. 2 The points and planes used in the cephalometric analysis Points: S-Sella : The midpoint of Sella turcica, N-Nasion : Nasofrontal suture, O-Orbitale : The most inferior point of orbit, Po-Porion : The midpoint of external auditory meatus, Co- Condylion : The most superior point of condyle, ANS-Anterior Nasal Spine : The most anterior point of anterior nasal spine, PNS-Posterior Nasal Spine : The most posterior point of hard palate, A-Subspinale : The most concave point of anterior maxilla, B-Supramentale : The most concave point above the chin, Pg-Pogonion : The most anterior point of the chin, Gn-Gnathion : The midpoint of Pg and Me point, Me-Menton : The most inferior point of the chin, Go-Gonion ; The most inferior and posterior point of angle of mandible, UL-Upper Lip point : The most anterior point of upper lip, LL-Lower Lip point : The most anterior point of lower lip, PG-Soft tissue pogonion, E-plane : Tip of nose to PG, FH plane-Frankfort horizontal plane : O to Po, Palatal plane : ANS to PNS, Functional occlusal plane : The average point of occlusion, Mandibular plane : Me to lower border of mandible

In this study, the custom analysis recommended by Pancherz [24] was also used in order to illustrate the sagittal and vertical changes of dentoskeletal relationship. In each subject, the Nasion (N) and Sella (S) points from the earlier film were transferred to the later film for comparison by using superimposition on the anterior wall of sella turcica, contour of the cribiform plate or planum sphenoidale of the ethmoid bone with registration on SE point (Greater wings of sphenoid intersect planum spenoidale) for cranium superimposition. [25] The occlusal line (OL)/occlusal line perpendicular (OLp) of the original film or earlier film were used as reference line to measure the cephalometric variables. The occlusal line (OL) was a line tangent to bisecting the incisal overbite and disto-buccal cusp of maxillary permanent first molar. The occlusal line perpendicular (OLp) was a line perpendicular to OL and passed through point S. The points and planes used in this Pancherz analysis were shown in Figure 3.

Ten custom analysis variables were generated to compare between 2 groups as follows:

The custom analysis Skeletal: Anteroposterior
Maxillary jaw base position (ANS/OLp)
Mandibular jaw base position (Pog/OLp)
Condylar position (Ar/OLp)
Mandibular length (Pog/OLp + Ar/OLp)
Dentoalveolar
Maxillary incisor position (is/OLp)
Maxillary molar horizontal position (ms/OLp)
Maxillary molar vertical position (ms point tangent perpendicular to SN)
Mandibular incisor position (ii/OLp)
Mandibular molar horizontal position (mi/OLp)
Mandibular molar vertical position (mi point tangent perpendicular to mandibular plane)

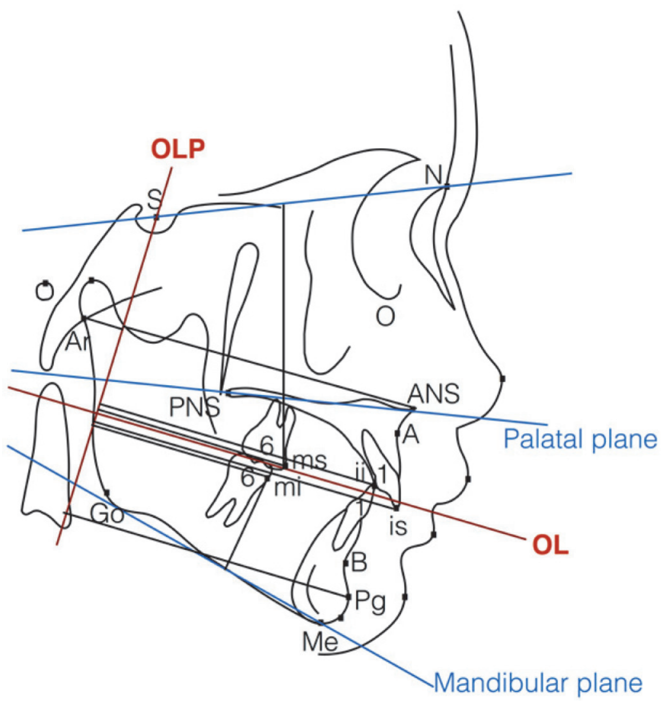

Fig. 3 The points and planes used in the Pancherz analysis
Points: **is** – the incisal tip of maxillary central incisor, **ii** – the incisal tip of mandibular central incisor, **ms** – mesial contact point of maxillary first molar, **mi** – mesial contact point of mandibular first molar Lines: **OL** - a line tangent to bisecting the incisal overbite and disto-buccal cusp of maxillary permanent first molar, **OLP** - a line perpendicular to OL and passed through point S

Is/OLp- ANS/OLp and ms/OLp – ANS/OLp indicate the position of maxillary incisors and maxillary first molars when compared to maxillary base, respectively. In addition, ii/OLp – Pog/OLp and mi/OLp – Pog/OLp indicate the position of mandibular incisors and mandibular first molars when compared to mandibular base, respectively.

Then, overjet correction (OJ correction) was calculated from the difference of is/OLp and ii/OLp and molar correction was calculated from the difference of ms/OLp and mi/OLp. Skeletal changes were calculated from the difference of ANS/OLp and Pog/OLp. The amount of skeletal changes was shown as percentage from the proportion of skeletal changes according to overjet and molar correction. The remaining amount of the overjet and molar correction was dentoalveolar changes that were shown to compare with skeletal changes.

The magnification of lateral cephalometric radiographs of the control and all treatment groups was adjusted for proper comparison. All measurements were performed twice by one examiner, and the mean value was calculated and used for evaluation.

The subjects were divided into 2 different vertical growth patterns, hyperdivergent and normovergent groups, by SN-MP angle. Hyperdivergent and normovergent groups were compared. The normovergent group consisted of the patients who had SN-MP = 30 ± 5.61°. [26] Patients who had SN-MP more than one SD (>35.61°) were considered to be the hyperdivergent group. These subjects included 17 hyperdivergent [9 boys and 8 girls], and 26 normovergent [16 boys and 10 girls] patients. The mean age of the hyperdivergent group and normovergent group at T1 was 10.98 ± 1.34 (ranges from 8 years 11 months to 13 years 10 months) and 11.90 ± 1.58 years old (ranges from 8 years 7 months to 14 years 11 months), respectively. The mean age of the hyperdivergent group and normovergent group at T2 was 12.80 ± 1.03 (ranges from 11 years 8 months to 15 years 1 month) and 13.19 ± 1.15 years old (ranges from 11 years 3 months to 15 years 8 months), respectively.

Assessment of skeletal maturation

The pretreatment (T1) hand wrist radiographs were analyzed to assess skeletal maturation of the subjects before treatment by using Grave and Brown method [27] that has nine stages of skeletal development.

Statistical analysis

Descriptive statistics. Mean differences and standard deviations were calculated for all variables between T1 to T2. The data were analyzed using a software (SPSS version 21).

For comparing the variables of the changes from the treatment (T2-T1) between hyperdivergent and normovergent patients, the data of each variable were examined by normal distribution. An independent t-test was used to compare the dentoskeletal changes and shown in the table with mean difference and standard deviation. Significance was determined at the p value ≤ 0.05(*), 0.01(**), 0.001(***).

Intra-observer method error was performed using Dahlberg's formula [28]. The analysis was determined by tracing and measuring the variables of 10 randomly selected lateral cephalometric radiographs. The standard deviation of difference was calculated by using the following formula:

$$SDd = \sqrt{\sum (d_1 - d_1)^2 / (2N)}$$

The limit within 95% of the differences between the two measurements that were expected to lie was ±2SDd; d_1 – first measurement; d_2 – second measurement at 6 months later; N = 10. The average method error did not exceed ±0.35 mm for linear measurements and did not exceed ±0.72 degrees for angular measurements. These errors were expected to have insignificant effects on reliability of the results of this study.

Results

The results of the cephalometric analysis comparing treatment changes between hyperdivergent and normovergent groups were shown in Table 1. The average treatment time was 15.00 ± 4.37 months for hyperdivergent group, and 14.19 ± 5.26 months for normovergent group. According to MU analysis, there were 7 variables from 30 variables that were statistically different. Normovergent group showed a statistically significant greater improvement in sagittal skeletal changes (increased SNB, decreased ANB, improved AF-BF, and increased Pg to N perpend) when compared to the hyperdivergent group. There was no significant difference of vertical skeletal changes between the two groups except the mandibular angle which showed a slight increase after twin block treatment in the normovergent group (1.41 ± 2.46°). Although there was no significant difference in the amount of upper incisal retroclination between both groups, however, lower incisors were more proclined ($p<0.05$) in hyperdivergent patients. Mandibular length increased in both groups according to the CoGn variable (5.47 ± 3.08 mm in hyperdivergent group, and 5.92 ± 3.22 mm in normovergent group) and the increase of the CoGn was not statistically significantly different between these groups ($p<0.05$).

The results of the custom analysis of these groups were shown in Table 2. There were no statistically significant differences in the variables. Skeletal changes (Pog-ANS) were 1.64 ± 1.75 mm in the hyperdivergent group, and 2.50 ± 2.18 mm in the normovergent group that was not significantly different between 2 groups. The amount of skeletal changes of the normovergent group according to overjet and molar correction (52.08%, 58.69%, respectively) were more than the hyperdivergent group (36.61%, 47.53%, respectively).

The distribution in relation to the skeletal maturation was demonstrated in Figure 4. There was 1 male patient in the normovergent group that did not have hand wrist radiograph at T1.

According to assessment of skeletal maturation, most subjects were in pre-pubertal and pubertal growth spurt stage. There were 10 hyperdivergent patients [7 boys, 3 girls] and 11 normovergent patients [8 boys, 3 girls] in pre-pubertal stage to the beginning of pubertal growth spurt (PP2 to H, R stage). For the most intense growth potential (S and MP3cap stage), there were 6 hyperdivergent patients [2 boys, 4 girls] and 13 normovergent patients [7 boys, 6 girls] in these stages. Each group has 1 patient that skeletal maturation was after the end of the pubertal growth spurt.

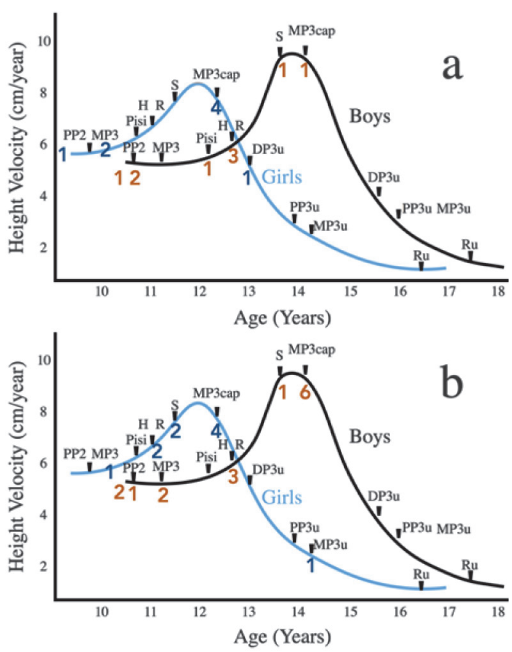

Fig. 4 Developmental stages from hand wrist radiograph of hyperdivergent and normovergent patients at T1: a. Hyperdivergent group, b. Normovergent group. The blue line and blue number showed the data of the female subjects, and the black line and orange number showed the data of the male subjects.

Table 1 Cephalometric values of the pretreatment (T1), posttreatment record (T2) and treatment effects (T2-T1) of hyperdivergent group and normovergent group-according to MU analysis. *P<0.05, **P<0.01, ***P<0.001.

Cephalometric value		Hyperdivergent T1 (n=17)		Hyperdivergent T2 (n=17)		T2-T1		Normovergent T1 (n=26)		Normovergent T2 (n=26)		T2-T1		Difference		P-value
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
	SNA	81.69	3.39	81.88	3.56	0.19	0.90	82.96	2.29	83.06	2.80	0.10	1.68	0.09	0.39	
	SNB	74.78	2.97	75.99	2.95	1.21	0.79	77.00	2.02	79.14	2.74	2.13	1.44	-0.93	0.38	*
	ANB	6.91	1.27	5.89	1.58	-1.02	0.87	5.96	2.24	3.92	2.25	-2.04	1.55	1.02	0.37	**
	A to N perpend. (mm)	1.22	2.84	0.86	2.69	-0.37	1.67	0.48	2.00	0.48	2.28	0.00	1.90	-0.36	0.57	
Skeletal	Pg to N perpend. (mm)	-8.82	3.62	-8.46	3.54	0.37	2.83	-7.76	3.53	-4.82	4.44	2.94	3.16	-2.58	0.95	**
(Antero-posterior)	AF-BF (mm.)	9.74	1.90	9.19	2.52	-0.55	1.55	8.24	3.19	6.20	3.04	-2.04	2.27	1.50	0.63	*
	AO-BO (mm.)	1.48	1.97	-0.38	3.05	-1.86	2.53	0.66	2.83	-1.53	3.15	-2.19	2.78	0.33	0.84	
	Pg-NB (mm.)	0.72	1.15	0.76	1.08	0.04	0.57	1.18	0.95	1.13	0.91	-0.04	0.72	0.09	0.21	
	Co-A (mm.)	77.18	4.99	78.82	5.74	1.63	2.44	78.77	5.04	80.32	5.31	1.55	2.54	0.08	0.78	
	Co-Gn (mm.)	97.08	6.10	102.56	7.13	5.47	3.08	98.52	7.04	104.44	7.54	5.92	3.22	-0.44	0.99	
	Mand-Max difference	19.90	3.10	23.74	2.60	3.84	2.17	19.76	3.59	24.12	3.44	4.36	2.57	-0.52	0.76	
	SN-MP	38.98	1.84	38.91	1.82	-0.07	1.60	30.06	2.71	30.38	3.19	0.32	1.53	-0.39	0.49	
	MP-PP	29.52	4.68	29.02	4.60	-0.50	1.97	22.18	3.75	22.51	4.04	0.33	1.83	-0.83	0.59	
(Vertical)	Mandibular Angle	124.73	4.26	124.67	4.49	-0.06	1.31	117.77	6.86	119.18	6.05	1.41	2.46	-1.47	0.65	*
	PFH/AFH	58.85	5.27	59.07	5.55	0.22	1.42	59.92	8.81	60.82	9.71	0.90	2.59	-0.68	0.69	
	Facial index	86.39	6.83	84.03	5.53	-2.36	3.45	87.54	6.05	84.41	6.45	-3.13	2.96	0.77	0.99	
Dental	U1-NA	29.64	7.47	23.32	6.68	-6.32	5.06	34.47	8.04	28.31	6.43	-6.17	5.36	-0.15	1.64	
	U1-NA (mm.)	6.05	2.29	4.30	2.34	-1.75	1.43	7.26	3.50	5.43	2.22	-1.83	2.35	0.08	0.64	
	U1-SN	111.30	6.86	105.44	6.26	-5.86	5.49	117.43	7.83	111.11	6.88	-6.32	5.42	0.46	1.70	
	L1-NB	31.85	4.73	36.05	5.56	4.20	3.90	30.85	4.76	34.24	6.30	3.39	3.96	0.81	1.23	
	L1-NB (mm.)	7.57	1.77	9.20	2.18	1.63	1.03	6.69	1.93	8.01	2.59	1.32	1.10	0.30	0.34	
	L1-MP	97.62	5.57	101.64	5.27	4.02	4.42	103.56	5.14	104.85	6.82	1.28	3.90	2.73	1.28	*
	Inter-incisal angle	111.74	7.04	114.46	8.18	2.72	5.87	108.21	6.82	113.26	7.55	5.05	5.92	-2.33	1.84	
	Overjet (mm.)	7.37	1.33	2.72	1.74	-4.65	1.54	7.80	2.67	2.62	1.85	-5.18	2.76	0.53	0.74	
	Overbite (mm.)	4.18	1.28	2.04	1.53	-2.14	1.37	4.67	1.22	2.10	1.47	-2.57	1.85	0.43	0.52	
	Ant.max.alv.ht.(mm.)	26.01	2.36	27.46	2.07	1.45	2.01	24.85	2.76	25.95	3.12	1.11	1.11	0.35	0.48	
	Post.max.alv.ht.(mm.)	18.68	2.21	20.15	2.46	1.47	1.01	19.16	2.18	20.30	2.50	1.13	1.20	0.33	0.35	
Soft tissue	Naso-labial angle	92.28	13.15	98.54	13.64	6.26	6.04	94.00	10.37	95.10	9.64	1.10	8.21	5.17	2.32	*
	H-angle	20.75	2.52	18.10	3.43	-2.65	1.95	20.05	4.17	16.55	4.45	-3.50	2.79	0.85	0.78	
	Lower lip to E-plane (mm)	4.69	1.88	4.82	2.48	0.13	1.72	3.00	2.17	3.79	2.31	0.79	2.05	-0.66	0.60	

Tcble 2 Custom analysis of the pretreatment (T1), posttreatment (T2) and the treatment effects (T2-T1) of hyperdivergent group and normovergent group. *P<0.05, **P<0.01, ***P<0.001.

	Custom analysis variables	Hyperdivergent T1 (n=17)		Hyperdivergent T2 (n=17)		T2-T1		Normovergent T1 (n=26)		Normovergent T2 (n=26)		T2-T1		Difference		P-value
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Skeletal (Antero-posterior)	Maxilla : ANS to OLp	69.02	8.43	72.39	8.15	3.36	3.48	66.18	12.73	68.54	12.90	2.35	3.12	1.01	1.02	0.33
	Mandible : Pog/OLp	66.65	8.23	71.59	7.99	4.94	2.62	64.81	5.72	69.66	5.66	4.85	3.46	0.09	0.98	0.92
	Condylar position : Ar/OLp	6.91	3.26	7.48	3.52	0.56	1.28	9.64	3.16	9.95	3.16	0.32	0.98	0.25	0.35	0.48
	Mandibular length : Pog/OLp + Ar/OLp	73.57	9.38	78.92	9.07	5.36	3.08	74.44	6.33	79.58	5.65	5.13	3.81	0.23	1.11	0.84
Dentoalveolar	Maxillary incisor : is/OLp	78.33	8.69	80.12	8.19	1.79	3.59	76.02	6.41	76.79	5.87	0.77	3.73	1.02	1.15	0.38
	Maxillary molar horizontal position	46.67	6.58	48.58	6.18	1.90	2.27	46.56	6.90	48.34	7.79	1.78	2.50	0.13	0.75	0.87
	: ms/OLp	46.67	6.58	48.58	6.18	1.90	2.27	46.56	6.90	48.34	7.79	1.78	2.50	0.13	0.75	
	Maxillary molar vertical position	60.67	7.60	64.39	7.82	3.72	3.52	60.26	6.36	63.43	5.90	3.17	3.13	0.55	1.02	0.59
	: ms to SN line	60.67	7.60	64.39	7.82	3.72	3.52	60.26	6.36	63.43	5.90	3.17	3.13	0.55	1.02	
	Mandibular incisor : ii/OLp	70.67	8.39	76.77	8.70	6.10	3.17	67.15	8.81	72.44	10.15	5.29	3.68	0.81	1.09	0.46
	Mandibular molar horizontal position	46.32	6.49	51.59	6.78	5.26	2.61	42.49	7.95	48.07	10.10	5.58	4.08	-0.32	1.12	0.78
	: mi/OLp	46.32	6.49	51.59	6.78	5.26	2.61	42.49	7.95	48.07	10.10	5.58	4.08	-0.32	1.12	
	Mandibular molar vertical position	25.75	3.94	28.14	3.87	2.39	1.38	26.15	3.20	28.18	2.35	2.04	2.66	0.35	0.70	0.62
	: mi to Mandibular plane	25.75	3.94	28.14	3.87	2.39	1.38	26.15	3.20	28.18	2.35	2.04	2.66	0.35	0.70	
Difference	is/OLp - ii/OLp	7.91	1.58	3.43	1.99	-4.48	1.95	8.11	2.70	3.31	2.11	-4.80	2.50	0.31	0.72	0.66
	ms/OLp - mi/OLp	0.36	1.37	-3.09	1.91	-3.45	2.06	1.92	2.16	-2.34	3.43	-4.26	2.85	0.81	0.80	0.32
	is/OLp - ANS/OLp	9.62	2.08	7.91	2.22	-1.72	1.52	8.29	3.48	6.45	2.59	-1.84	2.11	0.13	0.59	0.83
	ii/OLp - Pog/OLp	4.14	3.14	5.26	3.61	1.11	1.43	3.37	5.14	4.15	5.03	0.78	1.46	0.33	0.45	0.47
	ms/OLp - ANS/OLp	-23.08	2.40	-24.32	2.45	-1.24	1.24	-20.12	17.84	-20.65	18.76	-0.54	1.97	-0.70	0.54	0.16
	mi/OLp - Pog/OLp	-21.00	3.80	-20.45	4.07	0.56	1.48	-22.80	9.16	-21.97	11.55	0.83	2.82	-0.27	0.74	0.72
	Skeleletal change (Pog-ANS)					1.64	1.75					2.50	2.18	-0.86	0.63	0.18
	OJ correction (%Skeletal : %Dental)					36.61 : 63.39						52.08 : 47.92				
	Molar correction (%Skeletal : %Dental)					47.53 : 52.47						58.69 : 41.31				

Discussion

We found that normovergent patients responded to the twin block appliance more favorably than hyperdivergent patients according to MU analysis but skeletal change in term of mandibular advancement was similar.

Skeletal assessment of sample

Most subjects were in pre-pubertal and pubertal growth spurt stage. Two subjects were in late puberty. Normovergent group had more subjects in pubertal growth spurt stage, S and MP3cap, than the hyperdivergent group (13 subjects in the normovergent group, and 6 subjects in the hyperdivergent group, respectively).

Chronological age of the normovergent group was more than the hyperdivergent group by approximately 1 year at T1 but they were similar at T2.

The skeletal aspect

No study in the past conducted to compare hyperdivergent and normovergent patients after treatment with twin block appliance, thus the treatment effects of studies, that would be mentioned below, were compared by similar SN-MP angle and were shown in appendix for more detailed. In our study, no maxillary restraint could be demonstrated. SNB angle increased 1.21 ± 0.79° for hyperdivergent group and 2.13 ± 1.44° for the normovergent group. The results in hyperdivergent group was less, while in normovergent group was more than the results of Mill et al.[3] who found that the SNB angle of twin block group increased 1.9° over the 14-month period that was similar to the period in this study. Average SN-GoGn of their study was 35.1 ± 4.3° that was in the range of hyperdivergent tendency patients. However, SN-MP of hyperdivergent group in our study was 38.98 ± 1.84° which was more than previous study.

From our study, normovergent group had more significantly improved SNB, ANB, Pg to N perpend, and AF-BF than the hyperdivergent group especially Pg to N perpend. However, CoGn was not statistically different in both groups (5.47 ± 3.08 mm in the hyperdivergent group and 5.92 ± 3.22 mm in the normovergent group). CoGn of the control group in the study of Mill et al. [3] that had similar mean time interval which was 2.30 ± 1.20 mm in a 13 month-period with mean age at the start of the treatment (T1) at 9 years 1 month. According to study of D'Anto et al. [29] who stated that mandibular elongation after treatment more than 2 mm was clinically significant. Therefore, mandibular elongation according to CoGn changes after treatment in our study were clinically significant. The average annualized increase in mandibular length in previous studies [3, 12, 14] of twin block appliance compared to the control group were 2.0-2.7 mm.

From our study, there were no statistically differences with the Pancherz analysis. Skeletal changes (Pog-ANS) of the hyperdivergent and normovergent groups were 1.64 ± 1.75 mm and 2.50 ± 2.18 mm, respectively that were not significantly difference. The result of normovergent group was more than skeletal changes in Sidlauskas's study [30] that were 1.60 mm. (1.60 mm maxillary base increase, 3.2 mandibular base increase). Average SN-MP of their study was 33 ± 3° that was in the range of normovergent patients. However, skeletal changes should be considered with caution since there were many factors such as magnification, measurement errors, superimposition errors etc.

The skeletal/ dental contribution for overjet correction was 36.6 /63.4 percent and molar correction was 47.5/52.5 percent in hyperdivergent group. While the skeletal/ dental contribution for overjet correction in normovergent group was 52.1/47.9 percent and molar correction was 58.7/41.3 percent. Some authors showed that the effects of twin block appliance was mainly due to dentoalveolar changes such as O'Brien et al. [18] and Sidlauskas [30].

The vertical dimension aspect

In our study, the subjects who had SN-MP angle more than 35.61° were considered to be hyperdivergent group that was from average SN-MP angle of normovergent group and 1SD in the study [26] of adult Thai norm because there were no any studies related to Thai child norm in each age. However, this value was approximate to the study of Chung et al.[31] which SN-MP angle for grouping as high-angle Class II subjects was more than 36° at about age 9 that originated from mean SN-MP angle of children age 8 to 11 demonstrated by Riedel [32]. Mean SN-MP angle of hyperdivergent subjects in the study of Chung et al. [31] was 39.41 ± 3.55° in boys and 39.50 ± 2.49° in girls at age 9. Similarly, SN-MP more than 35 degrees was used for grouping to be high angle group in the study of Karlsen [33].

Some authors found that orthopedic appliances enhancing condylar growth have been shown to redirect more posterior growth, which was not advantageous especially in treating hyperdivergent patients. [25] Increased inclination of the mandibular plane in relation to the occlusal plane caused decreased mandibular length values in hyperdivergent subjects. [34]

Most clinicians often think that changes of mandibular plane of hyperdivergent and normovergent patients were increased by the treatment of removable functional appliances. Our study demonstrated that the changes of SN-MP of both groups were clinically insignificant (-0.07 ± 1.60° in the hyperdivergent group and 0.32 ± 1.53° in normovergent group). The results of our study were in accordant with Sidlauskas [30], Siara-Olds et al. [35], and Giuntini et al[16]. Sidlauskas [30] showed that SN-MP increased 0.50 ± 0.90° in the twin block group while it was 0.20 ± 0.30° in the control group. Similarly, Siara-Olds et al. [35] demonstrated that the changes of SN-GoGn in the twin block group was -0.19° while it was -0.04° in the control group and they also concluded that the twin block appliance was the most effective in controlling mandibular plane angle. Giuntini et al. [16] reported that the change of Frankfort horizontal plane to mandibular plane was 0.20 ± 2.80° in the twin block group while it was -1.30 ± 2.0° in the control group.

In our study, there were no significant difference of vertical skeletal changes between the two groups except the mandibular angle which showed a slight increase after twin block treatment in the normovergent group. Growth study without treatment showed that the gonial angle and mandibular angle of both hyperdivergent and hypodivergent groups decrease with age, which tend to decrease the magnitude of skeletal imbalance from Nanda's study [36]. Untreated vertical growers show less increase of Sella-Nasion-Pogonion (SNPg), less decrease of mandibular plane angle and gonial angle than horizontal growers. [37] Garcia-Morales and Buschang[38] demonstrated that about 64% of 6-year-old children classified as having a high mandibular plane angle were still classified as such at 15 years; 28% had average mandibular angles, 8% had low mandibular angles. This implies that a young child's vertical pattern helps predict his/her adult status but not his/her growth changes in individual because it was changeable. In conclusion, there are variation of mandibular plane change due to growth. Therefore, apparent changes showed between group averages should not be expected for individual patients and early treatment of hyperdivergent patients cannot be justified because at this time we cannot predict whose malocclusions will aggravate. [39]

The dentoalveolar changes

Upper incisors retroclination and lower incisors proclination that resulted in overjet reduction significantly occurred after twin block treatment according to previous studies. [3, 12-16, 18, 30]

The average changes of lower incisor inclination (L1-MP) in this study showed 4.02 ± 4.42° for the hyperdivergent group and 1.28 ± 3.90° for the normovergent group. Some studies reported more lower incisor proclination (L1-MP) during treatment with twin block appliance than our study such as Lund and Sandler [12] (7.9°) and Mills et al. [3] (5.2°). Some studies found less lower incisor proclination after twin block treatment that was similar range to our study such as the study of Sidlauskas [30] (3.2°) which designed acrylic capping on the lower anterior teeth, and the study of Toth and McNamara [14] (2.8°) which designed labial bow and clear acrylic on lower anterior teeth. Thus, lower incisors proclination depends on the design of the twin block appliance on the lower anterior teeth. L1-NB, L1-MP, and ii/OLp to Pog/OLp in the hyperdivergent group were more than the normovergent group. It might be as a result of overjet correction. With similar overjet correction in both groups in this study, lower incisors in hyperdivergent patients tend to be more procline than normovergent patients that might be due to vertical growth pattern.

The soft tissue changes

Baysal et al. [40] showed that H angle in the twin block group decreased and lower lip moved anteriorly when compared to the control group. Soft tissue changes in this study supported the result of the above-mentioned study. After treatment, both groups had improved facial profile and increased lower lip position anteriorly. Increased nasolabial angle of both groups might be caused by upper incisors retroclination and retrusion. Nasolabial angle of the hyperdivergent group was statistically greater than the normovergent group. This might be caused by the difference in upper incisors retroclination and retrusion, or nasal growth whose normovergent group had more vertical growth than the hyperdivergent group. This difference of nasal growth might be caused by average age and number of patients in pubertal spurt of normovergent group that were higher than hyperdivergent group. Normally, both sexes showed an increase in nose height from 7 to 18 years especially in boys. Nasolabial angle in girls is greater than in boys and it decreases with age more in girls than in boys. The nasal growth rate of the boys and girls were found equally around the age of 12. [41]

We showed no significant change in Pancherz analysis regarding mandibular Length, the limitations in this study could be due to using two dimensional (2D) cephalometry which showed projection errors of mandibular curved structures. The projection errors led to inaccuracies and underestimation of mandibular Length.[42] Regarding the Pancherz analysis, the measure ment was based on the line perpendicular to occlusal plane, therefore it is vulnerable to occlusal plane change.

However, interceptive treatment should be attempted to correct skeletal class II problem, no matter it is normovergent or hyperdivergent.

There were many factors that affected the results of the study. Further studies with more subjects, longer observation duration and subgroup analysis divided by the same skeletal maturation are recommended for evaluating the treatment effects and stability of the twin block treatment.

Conclusions

- Skeletal change after twin block treatment in term of mandibular advancement was similar between 2 groups.
- According to MU analysis, normovergent patients responded to the twin block appliance more favorably than hyperdivergent patients.
- According to Pancherz analysis, the effects of Class II correction with twin block appliance in hyperdivergent patients were mainly

due to dentoalveolar changes because dental contribution for overjet correction was 63.4 percent and molar correction was 52.5 percent.

- In addition, treatment effects were also attributed to the design of the appliance, patient compliance, and operator's experience.

Conflict of Interest: The authors declare that they have no conflict of interest.

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Appendix

Table: Some results of our study were compared by similar SN-MP angle of other studies.

Author	Hyperdivergent group	Normovergent group	Control group
Our study	**SN-MP at T1; 38.98 ± 1.84°** SNB change; 1.21 ± 0.79° CoGn change; 5.47 ± 3.08 mm Skeletal change 1.64 ± 1.75 mm SN-MP change -0.07 ± 1.60°	**SN-MP at T1; 30.06 ± 2.71°** SNB change; 2.13 ± 1.44° CoGn change; 5.92 ± 3.22 mm Skeletal change 2.50 ± 2.18 mm SN-MP change 0.32 ± 1.53°	
Lund and Sandler [12]	SN-MP at T1; 35.2 ± 6.6° SNB change; 1.9 ± 2.0° SN-MP change; 0.1 ± 2.7°		SN-GoGn at T1; 33.4 ± 5.8° SNB change; 0.4 ± 1.0° SN-MP change; -0.5 ± 1.2°
Mill et al.[3]	SN-GoGn at T1; 35.1 ± 4.3° SNB; 1.9 ± 1.2° CoGn; 6.5 ± 2.1 mm		
Sidlauskas [30]		SN-MP at T1; 33 ± 3° SNB; 2.0 ± 1.5° Skeletal change; 1.6 mm SN-MP change 0.5 ± 0.9°	

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