



# Three-dimensional skeletal, dentoalveolar and temporomandibular joint changes produced by Twin Block functional appliance

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## Abstract

**Introduction** The aim of this study was to three-dimensionally analyze the net skeletal, dental, and temporomandibular joint (TMJ) treatment changes using Twin Block functional therapy in comparison to untreated subjects.

**Materials and methods** The study (Twin Block) group comprised 22 female patients with skeletal Class II malocclusion due to mandibular retrusion. A total of 18 skeletal Class II untreated female subjects were included as controls. Skeletal, dental, and TMJ changes were evaluated using pre- and posttreatment/observational by cone beam computed tomography (CBCT) images. The treatment changes were compared with the growth changes observed in the control group using independent t-tests.

**Results** Compared to the changes induced by normal growth, the effective mandibular length, ramus, and corpus lengths increased by 3.19, 3.47, and 2.69 mm ( $P < 0.001$  for all), respectively. The maxillary and mandibular incisors inclination and position were significantly reduced and increased, respectively ( $P < 0.001$ ). The maxillary first molars were significantly moved distally and intruded by 1 and 0.36 mm, respectively, while the lower first molars moved mesially and intruded by 2.18 and 0.59 mm, respectively. There was a significant change in the condylar dimensions: increase in length, width, and height by 1.28, 0.88, 1.59 on the right and by 1.60, 0.53, and 1.10 mm on the left sides, respectively. There was significant forward positioning of the right and left condyle by 1.5 and 1.3 mm, respectively.

**Conclusions** Treatment with the Twin Block functional appliance results in significant skeletal, dentoalveolar, and condylar changes in both dimensions and positions.

**Keywords** Class II malocclusion · Functional orthopedic appliance · Twin Block · Temporomandibular joint · Cone beam computed tomography

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## Dreidimensionale skelettale, dentoalveoläre und temporomandibuläre Gelenkveränderungen nach Behandlung mit der Twin-Block-Apparatur

### Zusammenfassung

**Einleitung** Ziel der Studie war die Untersuchung skelettaler, dentaler und temporomandibulärer Veränderungen nach einer Twin-Block-Therapie im Vergleich mit einer unbehandelten Kontrollgruppe.

**Material und Methoden** Die Interventionsgruppe (Twin Block) umfasste 22 Patientinnen mit skelettaler Klasse-II-Malokklusion und Unterkieferrücklage. 18 unbehandelte Klasse-II-Patientinnen dienten als Kontrollgruppe. Skelettale, dentale und temporomandibuläre Veränderungen wurden anhand von DVT-Aufnahmen evaluiert, die vor und nach Behandlung bzw. während der Behandlung angefertigt worden waren. Mittels t-Tests für unabhängige Stichproben wurden die behandlungs- bzw. die wachstumsbedingten Veränderungen in der Interventions- und der Kontrollgruppe miteinander verglichen.

**Ergebnisse** Im Vergleich mit den Veränderungen, die sich wachstumsbedingt ergeben haben, erhöhten sich die effektive Unterkieferlänge sowie die Längen von Ramus und Corpus mandibulae um 3,19, 3,47 bzw. 2,69 mm ( $p < 0,001$  für alle). Inklination und Position der Oberkieferinzisivi verringerten sich signifikant ( $p < 0,001$ ), Inklination und Position der Unterkieferinzisivi erhöhten sich dagegen signifikant ( $p < 0,001$ ). Die ersten Molaren im Oberkiefer wurden signifikant um 1,0 bzw. 0,36 mm distalisiert und intrudiert, während die unteren ersten Molaren um 2,18 bzw. 0,59 mm mesialisiert und intrudiert wurden. Es gab signifikante Veränderungen an den Kondylen: Länge, Breite und Höhe vergrößerten sich um 1,28, 0,88 bzw. 1,59 auf der rechten und um 1,60, 0,53 bzw. 1,10 mm auf der linken Seite. Auf beiden Seiten kam es zu einer signifikanten Vorverlagerung der Kondylen um 1,5 (rechts) bzw. 1,3 mm (links).

**Schlussfolgerungen** Die Behandlung mit einem Twin-Block-Funktionsgerät führte zu signifikanten skelettalen, dentoalveolären und temporomandibulären Veränderungen.

**Schlüsselwörter** Klasse-II-Malokklusion · Funktionskieferorthopädie · Twin Block · Kiefergelenk · Digitale Volumentomographie

### Introduction

Class II malocclusion is commonly seen in orthodontic practice [26]. It causes esthetic, functional, and psychological disturbances of varying intensity. The severity of this malocclusion depends on the amount of anteroposterior discrepancy and its interaction with the related soft tissue structures. Patients with Class II Division 1 malocclusion can exhibit maxillary protrusion, mandibular retrusion, or a combination thereof, together with abnormal dental relationship and facial esthetic disorders [13, 23].

Mandibular retrognathism is a main contributor to Class II malocclusion [19], which necessitates the use of advancement or functional appliances. These appliances are designed to enhance and/or redirect the growth in a favorable direction [25].

Over the last 10 years, the Twin Block functional appliance developed by William J. Clark [8] has been the most popular functional appliance. Several clinical studies [5, 8, 16, 18, 20, 22, 24, 29, 30, 32, 33, 35] have been conducted to assess skeletal and dentoalveolar changes associated with Twin Block functional appliance therapy in Class II malocclusion. Concerning skeletal effects, some authors demonstrated a significant influence on mandibular growth [29, 33], while others [18, 24] claimed that it induced dentoalveolar changes with minimal skeletal effects.

A recently conducted systematic review [10] analyzed the effect produced by the Twin Block appliance concluded that it was not possible to analyze the effect of growth on the reported changes due to the limited data available. These studies were based on two-dimensional evaluation using lateral cephalometry with its intrinsic limitations that result in distorted images, enlarged in some areas and reduced in others, superimposition and inaccurate landmark localization [12]. On the other hand, recent systematic reviews [1, 14] investigated the effect of functional appliances on the temporomandibular joint (TMJ) found that there is a forward condylar positioning and remodeling but with minimally detailed results because the published three-dimensional study was either a pilot study [17] using class II elastics as a control group or a retrospective uncontrolled study [37].

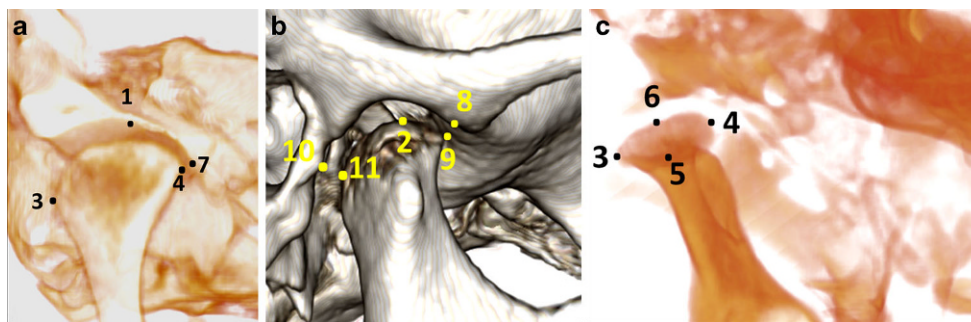
The aim of this study was to three-dimensionally analyze the net skeletal, dental, and TMJ treatment changes using Twin Block functional therapy by cone beam computed tomography (CBCT) with a comparable control group of untreated subjects.

### Materials and methods

This clinically controlled study conducted at the outpatient clinic of the Department of Orthodontics was approved by

**Fig. 1** Three dimensional temporomandibular joint landmarks: **a** coronal, **b** sagittal, **c** axial views. See Table 1 for explanation of numbers

**Abb. 1** Dreidimensionale Bezugspunkte am Kiefergelenk: **a** koronare, **b** sagittale, **c** axiale Sicht. Erläuterungen der Ziffern s. Tab. 1



the Research Ethics Committee (1/13-8-2011), Faculty of Oral and Dental Medicine, Cairo University, Egypt. All patients' parents were informed about the study procedures and informed written consents was obtained.

Sample size was calculated with an alpha value of 0.05 and a power of 90% based on the study conducted by Toth and McNamara [32]. They reported mean changes of Co-Gn (mandibular unit length) in the Twin Block group ( $5.7 \pm 2.4$  mm) and in the control group ( $2.7 \pm 1.5$  mm). Power analysis showed a minimum sample of 11 patients in each group.

The inclusion criteria were as follows: (1) females with a chronological aged between 10–13 years, (2) convex profile with retruded mandible, (3)  $\geq 1/2$  unit Class II molar and canine relationship, (4) overjet  $\geq 5$  mm, (5) skeletal age: stage 3 cervical vertebrae maturational indicators (CVMI) [5], (6) vertical growth pattern as verified clinically by steep mandibular plane, (7) no history of orthodontic treatment, (8) no history or clinically diagnosed TMJ disorders, and (9) free from any systemic disease or chronic medication use.

Based on the above criteria, 22 patients were included in the treatment group. CBCT images of 18 untreated clinically matching control patients were obtained from a control databank created by three research projects in the same institute [11]. All subjects in the control group were orthodontically treated after completion of the observational period.

All patients were scanned with CBCT to obtain detailed three-dimensional osseous evaluations of the TMJ and more accurate skeletal and dental measurements, while the control group data were obtained from the control databank of the institute. CBCT images were obtained using the commercially available Sirona GALILEOS CBCT machine (Sirona Dental Systems, Bensheim, Germany). Parameters of the CBCT scanner were set according to the recommendations of De Vos et al. [9] and provided a minimal set of CBCT device-related parameters to minimize the radiation dose to the minimum.

The treatment group subjects were treated with a standard Twin Block appliance according to Clark [8]. The patients were instructed to wear the appliance 24 h/day,

especially during mealtimes and they were followed once every 4 weeks. The anteroposterior dental arch relationship was checked with and without the appliance during each appointment. When no difference existed and the mandible could not be retruded, the active treatment period was then finished, retention period started with the appliance for another 3 months. The functional phase lasted for  $9.4 \pm 1.33$  months and the observational period for the control group was  $8.12 \pm 2.72$  months.

The skeletal, dentoalveolar, and temporomandibular (Fig. 1) three-dimensional landmarks (Table 1) were identified in CBCT images using Anatomage image processing software version 5.01. The skeletal, dentoalveolar, and temporomandibular (Fig. 2) three-dimensional measurements (Table 2) were obtained for all patients before the start of treatment (T0) and after the functional phase period (T1) in the treatment group and at the beginning (T0) and after 8 months (T1) of observation in the control group. Three-dimensional temporomandibular analysis was performed according to Alhammadi et al. [2–4], the intra- and interobserver reliability errors were analyzed by retracing CBCT projects 3 weeks after the first measurement.

### Statistical analysis

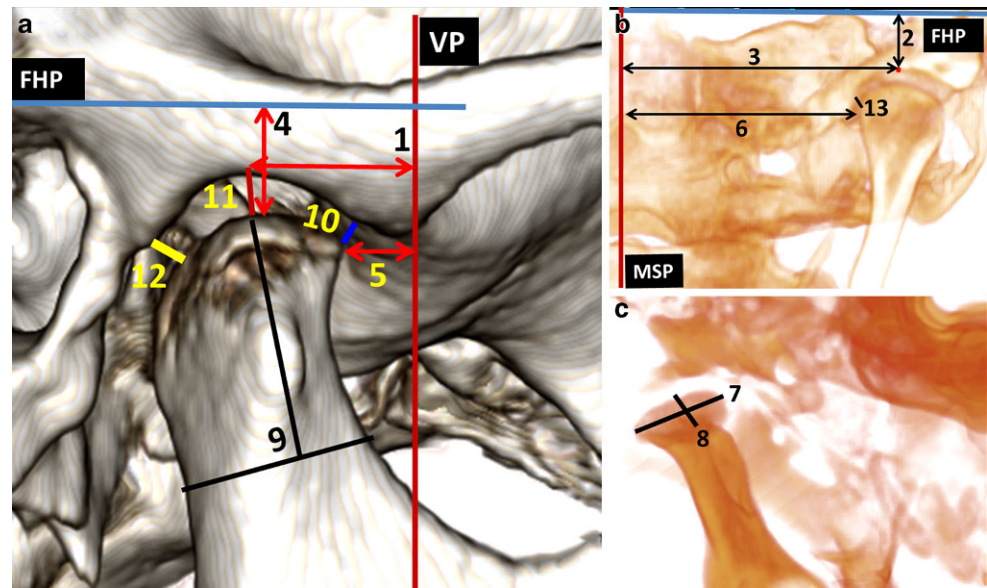
Statistical analysis was performed with SPSS\* Statistics Version 21 (IBM Corp., Armonk, NY, USA). Paired samples t-test was used to study the changes after treatment and observation period for all variables within the same group. Comparison of the change between the patients and control groups was carried out by independent samples t-test. Interobserver and intraobserver reliability analysis was carried out by concordance correlation coefficient (CCC).

### Results

The Twin Block and control groups comprised 18 participants each. In the treatment group, four patients dropped out at different times: two disappeared after the first month of treatment, one discontinued due to the psychological trauma upon using the appliance, one patient stopped using the ap-

**Fig. 2** Three dimensional temporomandibular joint measurements: **a** sagittal, **b** coronal, **c** axial views. See Table 2 for explanation of numbers. *VP* vertical plane, *MSP* midsagittal plane, *FHP* Frankfort horizontal plane

**Abb. 2** Dreidimensionale Messungen am Kiefergelenk: **a** sagittale, **b** koronale, **c** axiale Sicht. Erläuterungen der Ziffern s. Tab. 2. *VP* vertikale Ebene, *MSP* Midsagittale, *FHP* Frankfurter Horizontale



pliance after five months of improved facial profile. There was a significant clinical improvement of the soft tissue profile, molars and canines' relation, overjet, and overbite.

Intra- and interobserver reliability tests showed an excellent concordance correlation (0.903–0.970). Mean and standard deviation (SD) values of all skeletal, dental, and TMJ outcomes in starting form of the Twin Block/control group are presented in Tables 3 and 4, respectively. Mean and SD values of pre- and posttreatment and pre- and postobservational measurements of both groups are listed in Tables 5 and 6. The mean changes and differences between both groups for the same outcomes are presented in Tables 7 and 8.

Tables 3 and 4 showed that both groups are almost similar in the starting form with no significant differences between them except for four skeletal (AB diff (NV), PFH, Ag-Ag, and MP/SN) and three dental (LI-Nv, U6/FHP°, and LR6-LL6) measurements.

Compared to the changes induced by normal growth, Table 7 showed a net significant increase in both linear and angular anteroposterior facial profile measurements as indicated by ANB°, A-B diff Nv ( $P \leq 0.001$ ), and increase in the vertical facial profile measurements as demonstrated by AFH ( $P \leq 0.05$ ) and PFH ( $P \leq 0.001$ ), and subsequently the jarabak ratio; S-Go/N-Me ( $P \leq 0.001$ ).

The sole effect of the Twin Block on the maxillary base showed that there were no statistically significant changes in vertical position, effective maxillary length, maxillary base tipping, and maxillary base width. There was a significant increase in the palatal plane length (ANS-PNS) and minimal reduction in linear anteroposterior position of point A ( $P \leq 0.01$ ).

Comparison of the two groups showed that the net treatment effect on the mandibular base indicated that there was

significant movement in anteroposterior position by 1.53°, 1.87 mm ( $P < 0.001$  for all) as showed by SNB and both Nv-B and Nv-Pg, respectively. Similarly, the mandibular effective length, ramus length, and corpus length increased significantly by 3.19, 3.47, and 2.69 mm ( $P < 0.001$  for all), respectively. The vertical mandibular position, mandibular width, and mandibular plane inclination were not affected.

Regarding the dentoalveolar effects, compared to the minimal changes induced by normal growth, the maxillary incisors inclination and position were significantly reduced ( $P < 0.001$ ) by 7.98° and 2.57 mm, respectively. The mandibular incisor inclination and position was significantly increased by 3.32° and 1.82 mm, respectively. The net effect of the Twin Block showed that both overjet and overbite were significantly decreased by 4.89 and 2.11 mm, respectively. The maxillary first molars were significantly ( $P < 0.001$ ) moved distally and intruded by 1 and 0.36 mm, respectively, while the lower first molars moved mesially and intruded by 2.18 and 0.59 mm, respectively.

Results of the net effect of the Twin Block on the osseous TMJ components and joint spaces presented in Table 8 that showed a significant change in the condylar dimensions (increase in length, width, and height by 1.28, 0.88, 1.59 on the right and by 1.60, 0.53, and 1.10 mm on the left sides, respectively). There was significant forward positioning of the right and left condyle by 1.5 and 1.3 mm, respectively. This dimensional and positional change of the condyles results in a net decrease of the anterior (0.77 and 0.84 mm in the right and left side, respectively) and medial joint spaces (0.65 mm and 0.67 in the right and left side, respectively) and a net increase of the posterior (0.80 and 1.11 mm in the right and left side, respectively) and superior joint spaces (0.79 and 0.90 mm in the right and left side, respectively).

**Table 1** Definitions of skeletal, dental, and temporomandibular three dimensional landmarks in the study**Tab. 1** Definitionen der in der Studie verwendeten skelettalen, dentalen und temporomandibulären dreidimensionalen Bezugspunkte

No.	Landmark	Definition
<i>Skeletal landmarks</i>		
1	S	The center point of the pituitary fossa in the middle cranial fossa in sagittal and axial views
2	N	The most anterior and midpoint of the fronto-nasal suture
3	Or	The most inferior and middle point of each infra-orbital rim
4	Po	The most outer and superior bony points of the external acoustic meatus
5	ANS	The most anterior midpoint of the anterior nasal spine of the maxilla
6	PNS	The most posterior midpoint of the posterior nasal spine of the palatine bone
7	A point	The deepest midpoint of the maxillary anterior surface
8	B point	The deepest midpoint of the mandibular anterior surface
9	Me	The most inferior midpoint of the chin on the outline of the mandibular symphysis
10	Go	The right and the left midpoint on the angles of the mandible, halfway between the corpus and ramus
11	Gn	The most anterior and inferior point on the contour of the mandibular symphysis
12	Pg	The most anterior midpoint of the bony chin
13	Co	The most superior posterior point of the condylar head
14	J	Deepest point of the maxillary process
15	Ag	Deepest point of the antegonial notch
<i>Dental landmarks</i>		
1	Is	The most incisal and labial point on the most protruded upper incisors
2	Ii	The most incisal and labial point on the most protruded lower incisors
3	UI midT	The mid tooth of the most protruded upper incisors, estimated by the software
4	LI midT	The mid tooth of the most protruded lower incisors, estimated by the software
5	UI apex	Root apex of the most protruded upper incisors
6	LI apex	Root apex of the most protruded lower incisors
7	UI ap	The most anterior point on the labial surface of the most protruded upper incisors
8	LI ap	The most anterior point on the labial surface of the most protruded lower incisors
9	U6 tip	Cusp tip of the mesiobuccal cusp of the upper right and left first molars
10	U6 apex	Root apex of the mesiobuccal cusp of the upper right and left first molars
11	U6 fur	The furcation of the upper right and left first molars
12	U6 ap	The most anterior point on the mesial surface of the upper right and left first molars
13	L6 tip	Cusp tip of the mesial cusp of the lower right and left first molar
14	L6 apex	Root apex of the mesial cusp of the lower right and left first molars
15	L6 fur	The furcation of the lower right and left first molars
16	L6 ap	The most anterior point on the mesial surface of the lower right and left first molars
<i>Temporomandibular landmarks (Fig. 1)</i>		
1	MF	The most superior and midpoint of the hard tissue right or left mandibular fossa region
2	SCP	The most right or left superior point of the condylar head
3	LCP	The most right or left lateral point of the condylar head
4	MCP	The most right or left medial point of the condylar head
5	ACP	The most right or left anterior point of the condylar head
6	PCP	The most right or left posterior point of the condylar head
7	MJSf	The most right or left lateral point of the medial wall of mandibular fossa
8	AJSf	The most posterior point of the right or left anterior wall of the mandibular fossa opposed to the shortest anterior condylar-fossa distance
9	AJSc	The most anterior point of the right or left condyle opposed to the shortest anterior condylar-fossa distance
10	PJSf	The most anterior point of the right or left posterior wall of the mandibular fossa opposed to the shortest posterior condylar-fossa distance
11	PJSc	The most posterior point of the right or left condyle opposed to the shortest posterior condylar-fossa distance

**Table 2** Definitions of skeletal, dental, and temporomandibular measurements in the study**Tab. 2** Definitionen der in der Studie verwendeten skelettalen, dentalen und temporomandibulären Messwerte

No.	Measurements	Definition
<b>Facial profile measurements</b>		
1	ANB°	The angle between 3 point landmarks, A point, N and B point, determining the anteroposterior relation between maxilla and the mandible relative to the cranium
2	AB diff (NV) mm	The linear distance between point A and point B relative to nasion-vertical line, measuring the anteroposterior millimetric jaw relation relative to the cranium
3	AFH (mm)	The linear distance between point N and point Me, measuring the anterior facial height
4	PFH (mm)	The linear perpendicular distance between point S and point Inter-Gonion line, measuring the posterior facial height
5	S-Go/N-Me%	The ratio between the posterior facial height and the anterior facial height
<b>Maxillary base measurements</b>		
6	SNA°	The angle between 3 point landmarks S, N, and A point, determining the anteroposterior position of the maxilla relative to the cranial base
7	A-Nv (mm)	The linear distance measured between point A and Nv line, measuring the anteroposterior position of the maxilla relative to the nasion vertical line
8	N-A (mm)	The linear distance between point N and A point, determining the vertical position of the maxilla relative to the cranial base
9	ANS-PNS (mm)	The linear distance between points ANS and PNS measuring the maxillary base length
10	Co-A (mm)	The average of the bilateral linear distance between point Co and A point, measuring the effective mid facial length
11	J-J (mm)	The linear distance measured between the right and left jugal, measuring the maxillary base width
12	PP/SN°	The angle between the line S-N and palatal lines, measuring the palatal plane tipping relative to the cranium
<b>Mandibular base measurements</b>		
1	SNB°	The angle between 3 point landmarks S, N and B point, determining the anteroposterior position of the mandible relative to the cranial base
2	B-Nv (mm)	The linear distance measured between point B and Nv line, determining the anteroposterior position of the mandible relative to the nasion vertical line
3	Pg-Nv (mm)	The linear distance measured between point Pg and Nv line, determining the anteroposterior position of the chin relative to the nasion vertical line
4	N-B (mm)	The linear distance between point N and B point, determining the vertical position of the mandibular base relative to the cranial base
5	Co-Gn (mm)	The linear distance between point Co and Gn, measuring the effective mandibular length
6	Co-Go (mm)	The linear distance between points Co and Go, measuring the ramus length
7	Go-Gn (mm)	The linear distance between point Go and Gn, measuring the corpus length
8	Ag-Ag (mm)	The linear distance measured between the right and left antgonial notch, determining the mandibular base width
9	MP/SN°	The angle between the line S-N and the mandibular plane, measuring the mandibular base tipping relative to the cranium
<b>Dental measurements</b>		
<i>Maxillary and mandibular incisor measurements</i>		
1	UI/FHP°	The angle formed between the FH plane and the long axis of the most protruded upper incisor
2	UI-Nv (mm)	The linear distance between UIap and Nv line
3	LI/FHP°	The angle formed between the FH plane and the long axis of the most protruded lower incisor
4	LI-Nv (mm)	The linear distance between LIap and Nv line
5	UI/LI°	The angle formed between UI and LI long axes
6	Overjet (mm)	The difference between two measurements Is-Nv line and LIap-Nv line
7	Overbite (mm)	The difference between two measurements Is-FHP and Ii-FHP
<i>Maxillary and mandibular molar measurements (first molars)</i>		
8	U6/FHP°	The angle formed between the FH plane and the long axis of the upper first molar mesiobuccal root
9	U6-Nv (mm)	The linear distance between U6ap and Nv line
10	U6-FHP (mm)	The linear distance between U6 furcation and FH plane
11	L6/FHP°	The angle formed between the FH plane and the long axis of the lower first molar mesial root
12	L6-Nv (mm)	The linear distance between L6ap and Nv plane
13	L6-MP (mm)	The linear distance between point L6 furcation and the mandibular plane
14	UR6-UL6 (mm)	The linear distance between UR6 tip and UL6 tip
15	LR6-LL6 (mm)	The linear distance between LR6 tip and LL6 tip

**Table 2** (Continued)**Tab. 2** (Fortsetzung)

No.	Measurements	Definition
<b>Temporomandibular joint measurements</b> (Fig. 2)		
<i>Glenoid fossa measurements</i>		
–	Vertical Plane (VP):	Plane through sella and perpendicular to the Frankfort Horizontal plane (FHP) and midsagittal plane (MSP)
1	MFs-VP (mm)	The perpendicular distance between the most superior bony point of the mandibular fossa and the vertical plane
2	MFs-FHP (mm)	The perpendicular distance between the most superior bony point of the mandibular fossa and the Frankfort horizontal plane
3	MFs-MSP (mm)	The perpendicular distance between the most superior bony point of the mandibular fossa and the midsagittal plane
<i>Condylar measurements</i>		
4	Cds-FHP (mm)	Vertical condylar position: the perpendicular distance between the most superior bony point of the mandibular condyle and the Frankfort horizontal plane
5	Cda-VP (mm)	Anteroposterior condylar position: the perpendicular distance between the most anterior bony point of the mandibular condyle and the vertical plane
6	Cdl-MSP (mm)	Mediolateral condylar position: the perpendicular distance between the most medial bony point of the mandibular condyle and midsagittal plane
7	CL (mm)	Condylar length: the linear distance between the most lateral and medial point of the mandibular condyle
8	CW (mm)	Condylar width: the linear distance between the most anterior and posterior point of the mandibular condyle
9	CH (mm)	Condylar height: perpendicular distance between most superior point of the mandibular condyle and condylar neck line
<i>Joint spaces measurements</i>		
10	JSa (mm)	Anterior joint space: the shortest distance between the most anterior condylar and the most posterior fossa points
11	JSs (mm)	Superior joint space: the shortest distance between the most superior condylar and the most inferior fossa points
12	JSp (mm)	Posterior joint space: the shortest distance between the most posterior condylar and the most anterior fossa points
13	JSm (mm)	Medial joint space: the shortest distance between the most medial condylar and the most lateral fossa points

## Discussion

All subjects who participated in the study were females. This is to rule out the gender effect as the mandibular growth was clearly sex and age dependent [27].

The excellent concordance correlation between intra- and interobserver reliability measurements indicated high and precise landmark identification with CBCT that cannot be obtained by another conventional modality used for assessment of the complex temporomandibular region. Regarding the craniofacial changes, the present study showed that the Twin Block appliance produced an orthopedic effect in both anteroposterior and vertical directions. This presented by improvement in the facial profile by reduction in both anteroposterior linear and angular measurements. This was emphasized by the cephalometric studies of Lund and Sandler [18], Mills and McCulloch [20], Trenouth [34] and Sharma et al. [29], and the three-dimensional study of Yildirim et al. [37].

The facial profile was improved by reduction in the vertical pattern of growth mainly in the expense of increase in the posterior facial height three times than that of the anterior facial height. These findings were not in accordance with those stated by Mills and McCulloch [21]. They found that the mandibular plane angle and the anterior facial height were significantly increased in the Twin Block

group more than the control group. They used the classical Twin Block appliance design without any modification specific for the vertical facial type patients.

There was a minimal restriction of maxillary forward growth that could be explained by the distal reciprocal force exerted on the maxilla (headgear effect) by the appliance. This finding was in accordance with the cephalometric studies [29, 31] and the three-dimensional study of Yildirim et al. [37]; others found no effect on the maxillary base [15, 28].

The significant net increase in the mandibular effective length (Co-Gn, 3.19 mm) must be emphasized. This increase was a net result of an increase in both ramal (3.47 mm) and body length (2.96 mm). The overall mandibular skeletal changes could be attributed to the increase in mandibular length by 3.19 mm and the change in mandibular position by 1.53°, 1.87 and 1.87 mm based on SNB, B-Nv and Pg-Nv, respectively. The reported increase in the current study was greater than the increase produced by Twin Block appliance as reported in randomized clinical trials (RCTs) and controlled clinical trials (CCT) included in a recent systematic review [10]. The vertical mandibular position, mandibular width, and mandibular plane inclination were not affected.

Most of the effect on the maxilla was dentoalveolar due to the headgear effect of the incorporated labial arch in

**Table 3** Means and standard deviations (SD) of skeletal and dental measurements before treatment in the Twin Block and control groups  
**Tab. 3** Skelettale und dentale Mittelwerte und Standardabweichungen (SD) vor der Behandlung in der Twin-Block- und der Kontrollgruppe

Measurements	Twin Block		Control		<i>P-Value</i>
	Mean	SD	Mean	SD	
Age	11.89	1.85	11.27	2.19	0.335
<b>Facial profile measurements</b>					
ANB°	8.28	1.19	7.51	1.81	0.171
AB diff (NV) mm	11.29	1.85	9.77	2.19	0.042*
AFH (mm)	107.97	3.73	107.21	4.24	0.861
PFH (mm)	61.60	3.95	63.16	2.14	0.004*
S-Go/N-Me%	0.55	0.04	0.59	0.04	0.002*
<b>Maxillary base measurements</b>					
SNA°	81.27	3.58	81.75	3.52	0.703
A-Nv (mm)	1.06	2.75	1.57	1.4	0.519
N-A (mm)	51.7	3.73	51.79	2.99	0.945
ANS-PNS (mm)	50.32	2.61	49.80	3.60	0.646
Co-A (mm)	81.81	3.66	82.09	4.18	0.843
J-J (mm)	58.09	3.63	58.36	2.48	0.803
PP/SN°	8.9	3.00	8.24	3.14	0.537
<b>Mandibular base measurements</b>					
SNB°	73.00	3.24	73.97	2.30	0.326
B-Nv (mm)	-10.05	3.29	-8.21	2.57	0.168
Pg-Nv (mm)	-10.28	4.06	-7.86	3.78	0.089
N-B (mm)	90.83	5.72	89.19	4.74	0.375
Co-Gn (mm)	108.24	4.44	107.90	4.07	0.817
Co-Go (mm)	40.08	4.7	38.02	3.49	0.162
Go-Gn (mm)	74.18	4.17	74.52	3.13	0.791
Ag-Ag (mm)	76.23	5.50	72.63	3.86	0.035*
MP/SN°	43.42	3.69	39.29	4.77	0.010*
<b>Dental measurements</b>					
<i>Maxillary and mandibular incisor measurements</i>					
UI/FHP°	116.27	5.64	118.93	4.06	0.126
UI-Nv (mm)	7.54	4.59	9.11	2.89	0.262
LI/FHP°	53.19	5.01	51.97	6.84	0.568
LI-Nv (mm)	-0.01	3.98	2.94	2.55	0.015*
UI/LI°	116.05	5.91	113.64	5.53	0.236
Overjet (mm)	8.68	1.75	8.74	1.44	0.912
Overbite (mm)	1.26	0.91	0.64	2.05	0.260
<i>Maxillary and mandibular molar measurements (first molars)</i>					
U6/FHP°	85.05	3.12	81.56	5.40	0.028*
U6-Nv (mm)	-18.11	3.03	-17.74	2.80	0.713
U6-FHP (mm)	-29.19	2.80	-30.13	2.43	0.309
L6/FHP°	67.58	7.06	68.98	4.77	0.519
L6-Nv (mm)	-19.55	3.25	-18.75	3.37	0.498
L6-MP (mm)	-49.50	2.62	-50.06	3.17	0.590
UR6-UL6 (mm)	46.43	3.19	47.08	2.03	0.484
LR6-LL6 (mm)	40.58	2.55	42.50	2.71	0.046*

$P \leq 0.05$  significant



**Table 4** Means and standard deviations (SD) of temporomandibular joint measurements before treatment in the Twin Block and control groups  
**Tab. 4** Mittelwerte und Standardabweichungen (SD) der Kiefergelenkmesswerte vor der Behandlung bzw. in der Twin-Block- und Kontrollgruppe

Measurements	Twin Block		Control		<i>P-Value</i>
	Mean	SD	Mean	SD	
<b>Right temporomandibular joint measurements</b>					
<i>Glenoid fossa measurements</i>					
MFs-VP (mm)	-11.20	3.18	-11.66	2.55	0.625
MFs-FHP (mm)	0.91	2.06	0.30	0.97	0.273
MFs-MSP (mm)	44.15	1.52	43.74	1.71	0.476
<i>Condylar measurements</i>					
CdS-FHP (mm)	1.1	1.63	-2.24	0.90	<0.001*
Cda-VP (mm)	-2.61	3.37	-4.90	2.36	0.036*
Cdl-MSP (mm)	47.1	2.36	45.9	2.60	0.215
CL (mm)	15.86	1.84	15.66	1.65	0.748
CW (mm)	7.18	1.12	7.08	0.94	0.793
CH (mm)	8.99	1.47	9.76	1.36	0.128
<i>Joint spaces measurements</i>					
JSa (mm)	2.45	1.02	1.96	0.53	0.086
JSs (mm)	2.90	0.61	2.92	0.84	0.939
JSp (mm)	2.58	0.98	3.06	0.83	0.136
JSm (mm)	3.64	0.97	3.68	0.98	0.925
<b>Left temporomandibular joint measurements</b>					
<i>Glenoid fossa measurements</i>					
MFs-VP (mm)	-12.39	3.78	-10.92	2.39	0.185
MFs-FHP (mm)	1.49	1.49	0.90	0.47	0.160
MFs-MSP (mm)	41.99	1.79	42.19	1.68	0.744
<i>Condylar measurements</i>					
CdS-FHP (mm)	0.78	1.73	-1.99	0.86	<0.001*
Cda-VP (mm)	-6.12	3.12	-4.72	2.43	0.157
Cdl-MSP (mm)	45.85	2.42	45.42	3.04	0.655
CL (mm)	15.63	1.62	15.82	1.93	0.760
CW (mm)	7.48	1.57	6.97	1.16	0.289
CH (mm)	9.64	2.07	9.76	1.36	0.843
<i>Joint spaces measurements</i>					
JSa (mm)	2.39	0.98	1.91	0.48	0.098
JSs (mm)	2.92	0.61	3.32	0.76	0.112
JSp (mm)	2.63	1.02	3.33	0.67	0.025*
JSm (mm)	3.84	1.01	4.42	1	0.116

$P \leq 0.05$  significant

the upper block. These resulted in palatal tipping of the maxillary incisors by  $7.98^\circ$  and displacement by 2.57 mm. The opposite effect occurred for the mandibular incisors as they tipped and displaced labially as those teeth are a part of the anchorage of the appliance with its inherent backward force. These incisors findings were in accordance with studies reported by Lund and Sandler [18], Mills and McCulloch [20, 21] and Jena et al. [15, 16]. Both skeletal and dentoalveolar effects were responsible for correction of both overjet and overbite.

The study group showed significant forward migration of the mandibular first molars accompanied with the back-

ward migration of the maxillary first molars. This reciprocal migration of the molars could be attributed to the forward mandibular posturing effect of the appliance and its reciprocal backward on the maxilla, which is consistent with previously reported results [15, 16, 18, 20, 21, 29].

To date, almost no three-dimensional detailed dimensional and positional study has assessed the effect of the Twin Block appliance on the mandibular condyle which is considered as a growth site of the mandible and plays an important role in the final adult dimension of the mandible. In this study, a detailed three-dimensional analysis was used to evaluate this complex area. The net treatment effect of

**Table 5** Means and standard deviations (SD) of pre- and posttreatment skeletal and dental measurements in both groups**Tab. 5** Durchschnittswerte und Standardabweichungen (SD) von skelettalen und dentalen Messwerten vor und nach der Behandlung in beiden Gruppen

Measurements	Twin Block				Control			
	Pretreatment measurements		Posttreatment measurements		Preobservation measurements		Postobservation measurements	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<b>Facial profile measurements</b>								
ANB°	8.28	1.19	5.80	1.67	7.51	1.81	7.84	2.12
AB diff (NV) mm	11.29	1.85	8.50	1.92	9.77	2.19	9.95	2.30
AFH (mm)	107.97	3.73	109.32	3.87	107.21	4.24	108.77	4.45
PFH (mm)	61.60	3.95	63.90	3.95	63.16	2.14	63.80	3.04
S-Go/N-Me%	0.55	0.04	0.58	0.03	0.59	0.04	0.59	0.04
<b>Maxillary base measurements</b>								
SNA°	81.27	3.58	80.93	3.30	81.75	3.52	81.66	3.34
A-Nv (mm)	1.06	2.75	0.31	2.67	1.57	1.4	1.62	1.72
N-A (mm)	51.7	3.73	51.68	4.02	51.79	2.99	51.82	3.17
ANS-PNS (mm)	50.32	2.61	50.90	2.52	49.80	3.60	49.67	3.60
Co-A (mm)	81.81	3.66	82.75	4.17	82.09	4.18	82.1	4.00
J-J (mm)	58.09	3.63	58.12	3.41	58.36	2.48	58.20	2.39
PP/SN°	8.9	3.00	9.60	3.52	8.24	3.14	8.27	3.27
<b>Mandibular base measurements</b>								
SNB°	73.00	3.24	74.49	2.87	73.97	2.30	73.92	2.24
B-Nv (mm)	-10.05	3.29	-8.47	2.89	-8.21	2.57	-8.50	2.42
Pg-Nv (mm)	-10.28	4.06	-8.59	3.69	-7.86	3.78	-8.03	3.70
N-B (mm)	90.83	5.72	92.64	5.39	89.19	4.74	89.92	4.81
Co-Gn (mm)	108.24	4.44	111.64	3.91	107.90	4.07	108.11	4.04
Co-Go (mm)	40.08	4.7	40.08	4.74	38.02	3.49	38.02	3.49
Go-Gn (mm)	74.18	4.17	76.80	3.67	74.52	3.13	74.45	3.29
Ag-Ag (mm)	76.23	5.50	77.06	5.85	72.63	3.86	73.00	3.92
MP/SN°	43.42	3.69	43.24	4.17	39.29	4.77	39.70	4.58
<b>Dental measurements</b>								
<i>Maxillary and mandibular incisor measurements</i>								
UI/FHP°	116.27	5.64	109.33	4.30	118.93	4.06	119.97	4.11
UI-Nv (mm)	7.54	4.59	5.57	3.69	9.11	2.89	9.72	2.94
LI/FHP°	53.19	5.01	50.57	4.48	51.97	6.84	52.66	6.96
LI-Nv (mm)	-0.01	3.98	1.53	3.72	2.94	2.55	2.65	2.40
UI/LI°	116.05	5.91	121.61	5.09	113.64	5.53	113.02	5.60
Overjet (mm)	8.68	1.75	4.46	1.19	8.74	1.44	9.42	1.53
Overbite (mm)	1.26	0.91	3.13	0.75	0.64	2.05	0.3	1.95
<i>Maxillary and mandibular molar measurements (first molars)</i>								
U6/FHP°	85.05	3.12	84.93	4.09	81.56	5.40	81.83	4.10
U6-Nv (mm)	-18.11	3.03	-18.91	3.44	-17.74	2.80	-17.50	2.69
U6-FHP (mm)	-29.19	2.80	-29.40	2.78	-30.13	2.43	-30.70	2.45
L6/FHP°	67.58	7.06	66.51	6.76	68.98	4.77	68.67	4.98
L6-Nv (mm)	-19.55	3.25	-17.37	2.78	-18.75	3.37	-18.16	3.55
L6-MP (mm)	-49.50	2.62	-50.05	2.62	-50.06	3.17	-49.32	3.29
UR6-UL6 (mm)	46.43	3.19	46.56	3.29	47.08	2.03	47.26	1.77
LR6-LL6 (mm)	40.58	2.55	40.97	2.26	42.50	2.71	42.57	2.67

**Table 6** Means and standard deviations (SD) of the pre- and posttreatment temporomandibular joint measurements**Tab. 6** Mittelwerte und Standardabweichungen (SD) der Kiefergelenkmesswerte vor und nach der Behandlung in beiden Gruppen

Measurements	Twin Block				Control			
	Pretreatment measurements		Posttreatment measurements		Preobservation measurements		Postobservation measurements	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<b>Right temporomandibular joint measurements</b>								
<i>Glenoid fossa measurements</i>								
MFs-VP (mm)	-11.20	3.18	-11.02	3.34	-11.66	2.55	-11.51	2.33
MFs-FHP (mm)	0.91	2.06	0.80	1.90	0.30	0.97	0.09	0.96
MFs-MSP (mm)	44.15	1.52	44.61	1.72	43.74	1.71	43.54	1.50
<i>Condylar measurements</i>								
CdS-FHP (mm)	1.1	1.63	0.68	1.4	-2.24	0.90	-2.13	0.86
Cda-VP (mm)	-2.61	3.37	-1.11	3.46	-4.90	2.36	-4.90	2.28
Cdl-MSP (mm)	47.1	2.36	47.18	2.47	45.9	2.60	45.45	1.80
CL (mm)	15.86	1.84	17.15	1.91	15.66	1.65	15.68	1.70
CW (mm)	7.18	1.12	8.15	1.37	7.08	0.94	7.17	1.04
CH (mm)	8.99	1.47	10.34	1.42	9.76	1.36	9.51	1.52
<i>Joint spaces measurements</i>								
JSa (mm)	2.45	1.02	1.56	0.72	1.96	0.53	1.85	0.49
JSs (mm)	2.90	0.61	3.61	0.92	2.92	0.84	2.85	0.65
JSp (mm)	2.58	0.98	3.60	0.66	3.06	0.83	3.28	0.77
JSm (mm)	3.64	0.97	3.01	0.89	3.68	0.98	3.70	0.91
<b>Left temporomandibular joint measurements</b>								
<i>Glenoid fossa measurements</i>								
MFs-VP (mm)	-12.39	3.78	-12.94	3.05	-10.92	2.39	-10.92	2.42
MFs-FHP (mm)	1.49	1.49	1.24	1.28	0.90	0.47	1.11	0.62
MFs-MSP (mm)	41.99	1.79	42.30	1.37	42.19	1.68	42.08	1.95
<i>Condylar measurements</i>								
CdS-FHP (mm)	0.78	1.73	0.36	1.45	-1.99	0.86	-1.82	0.75
Cda-VP (mm)	-6.12	3.12	-4.67	2.80	-4.72	2.43	-4.56	2.52
Cdl-MSP (mm)	45.85	2.42	45.60	2.68	45.42	3.04	45.28	3.17
CL (mm)	15.63	1.62	17.15	1.69	15.82	1.93	15.75	1.97
CW (mm)	7.48	1.57	8.27	1.28	6.97	1.16	7.21	1.23
CH (mm)	9.64	2.07	10.61	1.52	9.76	1.36	9.63	1.40
<i>Joint spaces measurements</i>								
JSa (mm)	2.39	0.98	1.44	0.58	1.91	0.48	1.81	0.61
JSs (mm)	2.92	0.61	3.78	0.89	3.32	0.76	3.27	0.83
JSp (mm)	2.63	1.02	3.78	0.57	3.33	0.67	3.36	0.79
JSm (mm)	3.84	1.01	3.1	1.03	4.42	1	4.34	0.84

 $P \leq 0.05$  significant

the Twin Block appliance showed forward displacement of the condyles relative to the vertical plane and this attributed to the forward posturing of the mandible by the appliance. This finding was in agreement with the finding reported by the cephalometric study of Baccetti et al. [5], the CBCT study of Liu et al. [6] and an MRI study by Chavan et al. [7].

Regarding the dimensional effect on the condyle, there was a more significant increase in the condylar length, width, and height on both sides by an average of 1.45 mm, 0.7 mm, and 1.35 mm, respectively. A recent uncontrolled

study assessing the effect of the Twin Block appliance of the condylar volume showed a significant volume increase of 347 mm<sup>3</sup> in the left and 273 mm<sup>3</sup> in the right condyles. This increase gives an indication of three-dimensional increase of the condylar dimension [36].

Regarding evaluation of the mandibular joint spaces, a more significant increase in the superior and posterior joint spaces was observed, while there was a significant decrease in the anterior and medial joint spaces. This could be explained by the normal sequence of the anterior and inferior

**Table 7** Means and standard deviations (SD) of skeletal and dental changes in both groups**Tab. 7** Mittelwerte und Standardabweichungen (SD) der skelettalen und dentalen Veränderungen in beiden Gruppen

Measurements	Twin Block		Control		Diff. of Means	SEM	P-Value
	Mean	SD	Mean	SD			
<b>Facial profile measurements</b>							
ANB°	-2.48	0.79	0.33	0.50	2.80	0.22	<0.001*
AB diff (NV) mm	-2.79	0.85	0.18	0.36	2.97	0.23	<0.001*
AFH (mm)	1.35	1.19	0.56	0.66	0.78	0.34	0.033*
PFH (mm)	3.70	1.24	-0.25	0.29	-3.95	0.32	<0.001*
S-Go/N-Me%	0.02	0.01	-0.01	0.01	-0.03	0.00	<0.001*
<b>Maxillary base measurements</b>							
SNA°	-0.34	0.56	-0.09	0.51	0.25	0.19	0.187
A-Nv (mm)	-0.75	1.14	0.05	0.46	0.80	0.31	0.02*
N-A (mm)	-0.02	2.76	0.03	0.60	0.06	0.72	0.937
ANS-PNS (mm)	0.64	0.88	-0.12	0.60	-0.77	0.26	<0.01*
Co-A (mm)	0.94	1.73	0.016	1.06	-0.92	0.51	0.0860
J-J (mm)	0.04	0.39	-0.16	0.55	-0.20	0.17	0.254
PP/SN°	0.07	1.80	0.03	0.45	-0.66	0.47	0.187
<b>Mandibular base measurements</b>							
SNB°	1.49	0.91	-0.05	0.56	-1.53	0.26	<0.001*
B-Nv (mm)	1.58	1.20	-0.29	0.44	-1.87	0.33	<0.001*
Pg-Nv (mm)	1.70	0.62	-0.17	0.65	-1.87	0.22	<0.001*
N-B (mm)	1.80	2.35	0.72	0.41	-1.07	0.56	0.102
Co-Gn (mm)	3.40	2.38	0.21	0.84	-3.19	0.60	<0.001*
Co-Go (mm)	3.61	1.50	0.13	0.82	-3.47	0.41	<0.001*
Go-Gn (mm)	2.62	1.50	-0.06	0.50	-2.69	0.38	<0.001*
Ag-Ag (mm)	0.83	1.28	0.37	0.84	-0.46	0.37	0.240
MP/SN°	-0.17	1.16	0.42	0.52	0.59	0.30	0.085
<b>Dental measurements</b>							
<i>Maxillary and mandibular incisor measurements</i>							
UI/FHP°	-6.95	3.37	1.04	1.20	7.98	0.85	<0.001*
UI-Nv (mm)	-1.97	1.75	0.61	0.40	2.57	0.43	<0.001*
LI/FHP°	-2.63	1.78	0.69	1.24	3.32	0.53	<0.001*
LI-Nv (mm)	1.54	1.94	-0.29	0.53	-1.82	0.52	<0.01*
UI/LI°	5.56	3.02	-0.62	1.92	-6.18	0.87	<0.001*
Overjet (mm)	-4.22	1.59	0.68	0.48	4.89	0.42	<0.001*
Overbite (mm)	-1.87	0.41	0.24	0.32	2.11	0.13	<0.001*
<i>Maxillary and mandibular molar measurements (first molars)</i>							
U6/FHP°	-0.12	3.79	0.27	1.19	0.38	0.10	0.708
U6-Nv (mm)	-0.80	1.64	0.24	1.00	1.04	0.48	0.044*
U6-FHP (mm)	-0.22	0.65	-0.57	0.23	-0.36	0.17	0.058*
L6/FHP°	-1.07	3.15	-0.31	1.40	0.76	0.87	0.396
L6-Nv (mm)	2.18	0.78	0.59	0.49	-1.59	0.22	<0.001*
L6-MP (mm)	-0.55	0.94	0.73	0.70	1.28	0.29	<0.001*
UR6-UL6 (mm)	0.12	0.47	0.18	0.73	0.05	0.22	0.808
LR6-LL6 (mm)	0.39	2.64	0.07	0.62	-0.32	0.69	0.654

\* $P \leq 0.05$  mild significant,  $P \leq 0.01$  significant,  $P \leq 0.001$  highly significant

Diff: difference

**Table 8** Means and standard deviations (SD) of the temporomandibular joint measurements changes in both groups  
**Tab. 8** Mittelwerte und Standardabweichungen (SD) der Veränderungen der Kiefergelenkmesswerte in beiden Gruppen

Measurements	Twin Block		Control		Diff. of Means	SEM	P-Value
	Mean	SD	Mean	SD			
<b>Right temporomandibular joint measurements</b>							
<i>Glenoid fossa measurements</i>							
MFs-VP (mm)	0.18	1.70	0.15	0.55	-0.03	0.45	0.946
MFs-FHP (mm)	-0.11	0.69	-0.21	0.80	-0.10	0.26	0.699
MFs-MSP (mm)	0.46	0.94	-0.21	0.79	-0.66	0.30	0.035*
<i>Condylar measurements</i>							
CdS-FHP (mm)	-0.42	0.89	0.11	0.44	0.53	0.25	0.046*
Cda-VP (mm)	1.49	0.65	-0.00	0.38	-1.50	0.18	<0.001*
Cdl-MSP (mm)	0.16	0.86	0.64	1.62	-0.62	0.44	0.170
CL (mm)	1.29	0.55	0.01	0.38	-1.28	0.16	<0.001*
CW (mm)	0.97	0.51	0.09	0.40	-0.88	0.16	<0.001*
CH (mm)	1.35	0.74	-0.24	0.57	-1.59	0.23	<0.001*
<i>Joint spaces measurements</i>							
JSa (mm)	-0.88	0.69	-0.11	0.33	0.77	0.19	<0.01*
JSs (mm)	0.71	0.65	-0.07	0.61	-0.79	0.21	<0.01*
JSp (mm)	1.02	0.75	0.22	0.35	-0.80	0.21	<0.01*
JSm (mm)	-0.63	0.18	0.02	0.34	0.65	0.10	<0.001*
<b>Left temporomandibular joint measurements</b>							
<i>Glenoid fossa measurements</i>							
MFs-VP (mm)	-0.55	1.28	0.00	0.43	0.55	0.34	0.132
MFs-FHP (mm)	-0.25	0.62	0.20	0.43	0.45	0.19	0.019*
MFs-MSP (mm)	0.31	1.53	-0.10	1.27	-0.42	0.49	0.393
<i>Condylar measurements</i>							
CdS-FHP (mm)	-0.42	0.94	0.17	0.46	0.59	0.26	0.039*
Cda-VP (mm)	1.45	0.69	0.15	0.46	-1.30	0.20	<0.001*
Cdl-MSP (mm)	-0.24	0.81	-0.17	0.65	0.60	0.25	0.792
CL (mm)	1.52	0.41	-0.08	0.47	-1.60	0.16	<0.001*
CW (mm)	0.77	0.57	0.24	0.38	-0.53	0.17	<0.01*
CH (mm)	0.97	0.98	-0.14	0.27	-1.10	0.26	<0.01*
<i>Joint spaces measurements</i>							
JSa (mm)	-0.94	0.58	-0.10	0.31	0.84	0.16	<0.001*
JSs (mm)	0.84	0.84	-0.05	0.45	-0.90	0.23	<0.001*
JSp (mm)	1.15	0.81	0.03	0.27	-1.11	0.22	<0.001*
JSm (mm)	-0.75	0.32	-0.08	0.36	0.67	0.12	<0.001*

\* $P \leq 0.05$  mild significant,  $P \leq 0.01$  significant,  $P \leq 0.001$  highly significant

Diff. difference

movement of the condyle by forward positioning of the mandible by the appliance.

## Conclusions

- Twin Block appliance therapy increase dimensions of mandibular condyle in the three planes of space and reposition toward a more forward position.
- Increased posterior and superior and decreased anterior and medial joint spaces are another indication of anterior and inferior positioning of the condyle.
- Significant improvement of the skeletal profile in antero-posterior and vertical direction; most of these changes were due to an increase in the effective mandibular, ramus, and corpus lengths and increase in posterior facial height, respectively.
- Palatal displacement of maxillary incisors, labial displacement of mandibular incisors, forward migration of the mandibular first molars, and backward migration of the upper molars were responsible for correction of overjet and molar relation, respectively.

**Conflict of interest** H.Y. Elfeky, M.S. Fayed, M.S. Alhammadi, S.A.Z. Soliman and D.M. El Boghdadi declare that they have no competing interests.

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