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The effects of functional treatment on the sagittal position of the mandibular condyle

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Abstract: The aim of the current study was to evaluate the effects of functional treatment appliances, a U-Bugel type I activator and a conventional activator, on the mandibular condyle considering the sagittal direction. Alterations in the growth direction and quantity of the condyle effects the ramal inclination and, consequently, the whole mandible. This situation is important when considering treatment prognosis and stability. The material consisted of pre- and post-treatment lateral cephalograms and hand-wrist films of 49 individuals having skeletal and dental Class II/div.1 malocclusions. Although the elimination of overjet and correction of Class II/div.1 anomalies was achieved, statistically significant changes were not observed in the sagittal direction of the mandibular condyle. (J. Oral Sci. 42, 195-203 , 2000)

Key words: functional treatment; sagittal direction; mandibular condyle.

Introduction

Relocation of the mandible in the sagittal direction can be achieved in Class II/div.1 cases by using the functional treatment method with activator appliances (1-4). Mandibular condylar cartilage is stimulated as a result of the relocation process (5,6). Because of the ability of the condylar cartilage to respond to mechanical stimulants, non high-angle Class II/div.1 cases with horizontal growth patterns can be treated with activator appliances (7-11). Petrovic (5) and Karwetzky (12) underscored that activator treatment directs the genetic determinant of condylar growth potential by condylar growth stimulation. The adaptive stimulation of cartilage tissue produces mandibular elongation by enchondral ossification. Adaptive condylar reactions by the stimulation of cartilage tissue cell division has been shown histologically in previous animal studies (5-6, 12-16). Hence, we aimed to determine if these reactions could be shown roentgenographically in human subjects that were treated by activator appliances. In case such adaptive reactions occur in humans, then permanent skeletal corrections could be done by re-directing condylar growth.

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Materials and Methods

Routine pre-treatment and post-treatment lateral cephalograms with hand-wrist films of 49 patients that had been treated with activator appliance at the university dental hospital were selected. The three material groups, the U-bugel type I activator-18 cases (17), the conventional type activator-14 cases (3) and the untreated control group, were studied. The control group consisted of lateral cephalograms and hand-wrist films of 17 individuals having Class II/div.1 malocclusions. Standard X-rays were taken at an interval that craniofacial development could be observed briefly. Hand film evaluation was carried out by numbering skeletal maturation periods from one to nine as described by Helm et al. and as shown in Fig. 1 (18-22).

Cephalometric analysis

All of the measurements were carried out using two different coordinate systems. The coordinate systems were, cranial base and mandible.

Cranial base: The horizontal plane (X-axis) was the line between the anterior clinoid process (T) and the point where the great wings of the sphenoid bone intersects the

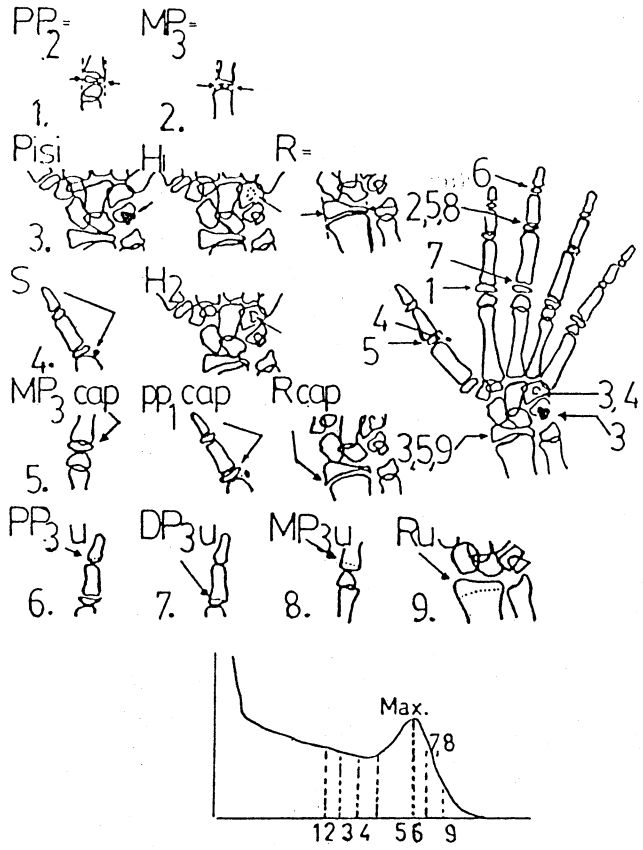


Fig. 1 Criteria for evaluating hand-wrist films.

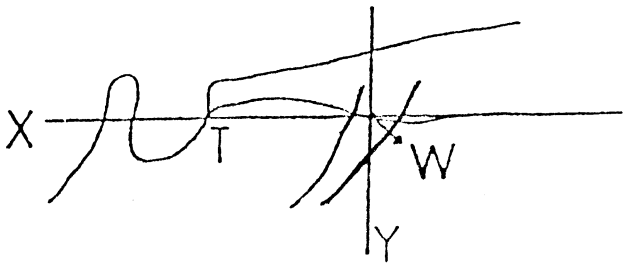


Fig. 2 Cranial base coordinate system.

sphenoidal plane (W). The Y-axis was a perpendicular line drawn to the horizontal axis from the W point (Fig. 2) (18-21).

Mandible: The parallel line to the X-axis from ramal center (xi) acted as the horizontal plane and a perpendicular line from the xi point to the horizontal plane was the vertical plane (Fig. 3) (22).

The cephalometric points used in this study were as follows (Fig. 4):

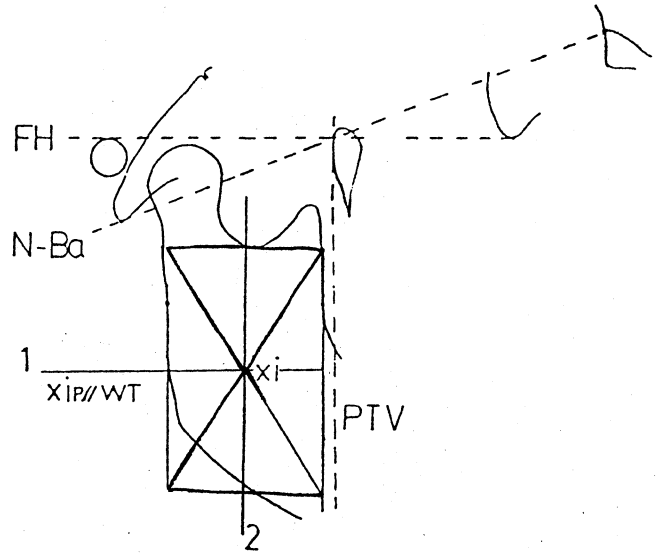


Fig. 3 Mandibular coordinate system.

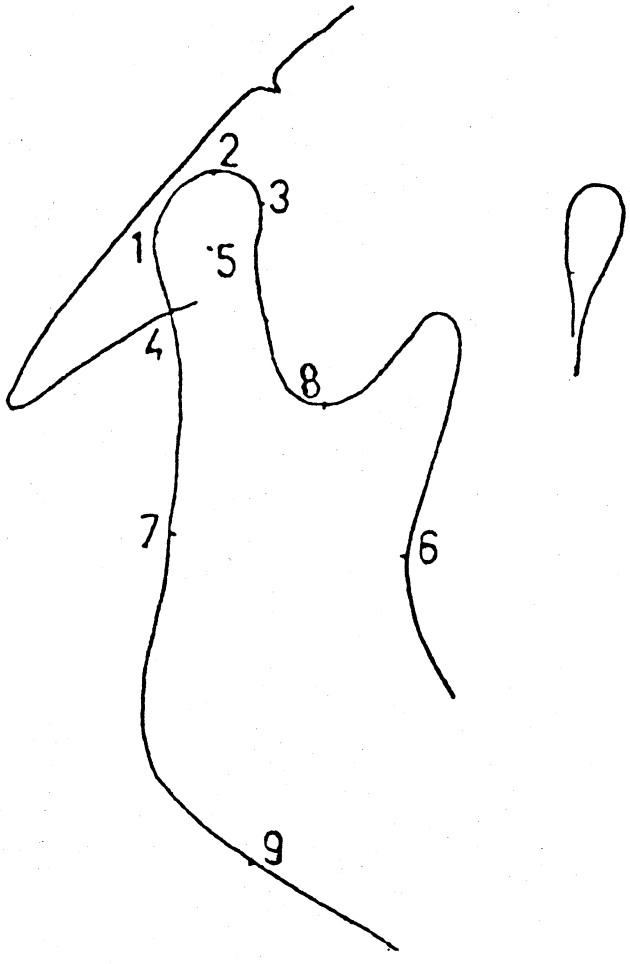


Fig. 4 Cephalometric points used.

1. Posterior condyle (PK).
2. Superior condyle (SK).
3. Anterior condyle (AK).
4. Articulare (Ar).
5. Center of condyle (C). The midpoint of the condyle on the basion-nasion plane.
6. The deepest point on the consavity of the anterior ramus border (R_1).
7. The parallel line drawn from R1 to FH intersecting the posterior border of ramus (R_2)
8. The deepest point of the sigmoid curvature (R_3).
9. The parallel line drawn from R3 to PTV where it intersects the inferior border of ramus (R_4) (23-24).

Projections of these points on sagittal planes were marked. The distance between the centers of the coordinate systems and projection points were measured (Figs. 5a, b). These points were classified according to their coordinate systems, for example PKx and PK1. FH, PTV and N-Ba planes were also used for standardization in determining the points as well as to minimize tracing and measurement errors (Fig. 3). Skeletal evaluation of sagittal and vertical dimensions were done regarding ANB and GoGn/SN angles.

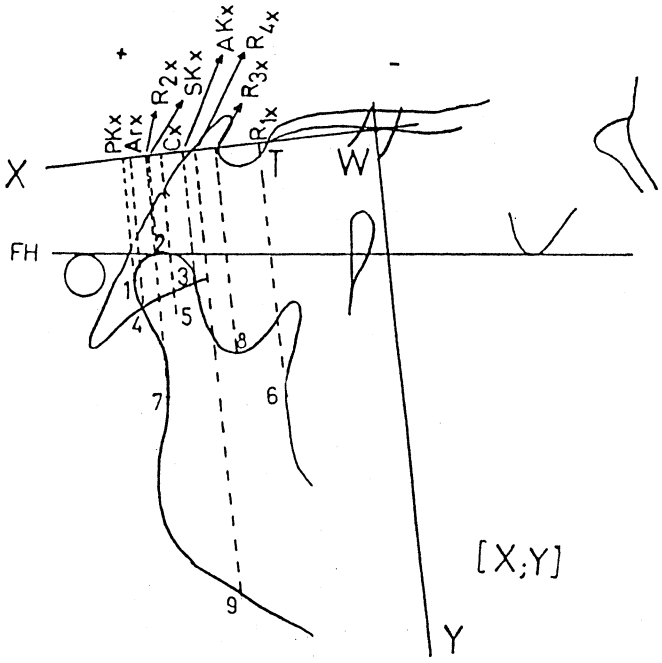


Fig. 5a Projection of cephalometric points to [X;Y] coordinate system.

Statistical methods

Tracing and measurement errors were evaluated in a previous study (25). The means (X) and standard deviations (Sx) of the measurements were calculated for all groups. Paired t tests were applied to test the statistical significance of differences between the mean values of the pre- and post-treatment measurements. The statistical differences between mean values of the groups and between pre- and post-treatment conditions were investigated using analysis of variance and Duncan's test.

Findings

The differences of skeletal maturation periods of 49 individuals in the pre- and post-treatment phases were found significantly different ($P < 0.01$) (Table 1).

There were no significant difference between the initial and final average maturation periods of all groups (Table 2).

The condylar measurements were evaluated in two groups:

1st Group- Cranial base coordinate system (X;Y).

2nd Group- Mandibular reference plane (1;2).

Both evaluations were made by measuring the projection dimension between the vertical axis and origin.

For the evaluation based on the (X;Y) axis, the mean values and standard deviations of the initial phase, the final phase and the differences of the three groups are presented

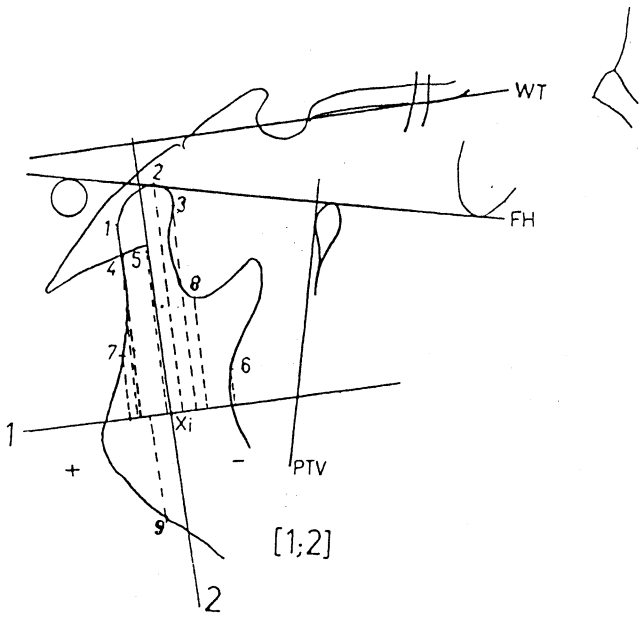


Fig. 5b Projection of cephalometric points to [1;2] coordinate system.

Table 1 Mean values of skeletal maturation periods of the groups

Skeletal Maturation Period	Group	N	Initial $X \pm S_x$	Final $X \pm S_x$	Difference $D \pm S_D$	Paired t test
	Control	17	3.34 0.81	5.50 1.33	2.16 0.52	**
	U-Bugel	18	2.96 0.70	4.52 1.06	1.56 0.37	**
	Activator	14	4.26 1.14	5.88 1.57	1.62 0.43	**

*P<0.05 **P<0.01

Table 2 The differences between the skeletal maturation periods of the groups

	Groups	N	D	$\pm S_D$	F
Skeletal Maturation Period	Control	17	2.16	0.52	-
	U-Bugel	18	1.56	0.37	-
	Activator	14	1.62	0.43	-

*P<0.05 **P<0.01

in Table 3. There were no statistically significant differences between these groups.

Table 4 gives the statistical evaluation regarding the mandibular reference line.

R21 and R41 parameters were found to be statistically significantly different ($P < 0.05$). ANB angle was $P < 0.01$ significant whereas GoGn/SN angle was $P < 0.01$ significant in control and $P < 0.05$ at activator group as shown in Table 5.

The initial and final findings of ANB and GoGn/SN angles are shown in Table 6.The initial difference in ANB angle ($P < 0.05$) may have been due to the significant difference ($P < 0.05$) between the control and the U-bügel activator groups. Final values of GoGn/SN angle was significantly different ($P < 0.05$) between the groups as a result of the difference of control group levels (Table 6).

Comparing the initial parameters on the X-axis, SKx measurement was significantly different as a result of differences in the control group (Table 7). R1-4x measurements were significantly different ($P < 0.05$) between the groups as a result of control and activator group differences.

Final values of R1x and R2x angle were significantly different ($P < 0.05$) between the groups as a result of the difference of the control and activator groups (Table 8).

Table 3 Means and standard deviations of initial, final and control phases regarding (X;Y) reference system

Parameter	Group	Initial $X \pm S_x$	Final $X \pm S_x$	Difference $D \pm S_D$	Paired t - test
PK_X	Control	42.85 1.25	43.93 1.31	1.08 0.99	
	U-Bugel	45.88 1.11	44.72 1.35	-1.15 0.99	
	Activator	46.70 1.10	47.20 1.22	1.50 0.92	
SK_X	Control	36.40 1.10	38.00 1.21	1.60 1.21	
	U-Bugel	40.08 1.06	39.32 1.24	-0.76 0.79	
	Activator	40.34 1.15	40.38 1.24	0.04 1.29	
AK_X	Control	32.03 1.19	32.35 1.27	0.32 0.97	
	U-Bugel	34.31 1.07	34.31 1.07	0.00 0.58	
	Activator	35.34 1.13	35.55 1.18	0.21 1.25	
Ar_X	Control	41.53 1.53	42.69 1.40	1.16 1.22	
	U-Bugel	44.22 1.20	43.92 1.37	-0.31 0.84	
	Activator	46.41 1.44	46.37 1.19	-0.04 1.26	
C_X	Control	36.62 1.58	36.71 1.36	0.09 1.35	
	U-Bugel	38.37 1.21	38.89 1.37	0.52 0.67	
	Activator	40.79 1.41	40.70 1.27	-0.09 1.26	
R_{1X}	Control	8.69 2.01	10.50 1.81	1.81 1.51	
	U-Bugel	13.90 1.22	13.58 1.42	-0.32 0.98	
	Activator	17.96 2.58	16.34 1.51	-1.62 1.88	
R_{2X}	Control	37.96 1.96	39.79 1.84	1.84 1.25	
	U-Bugel	43.13 1.42	42.37 1.59	-0.75 0.86	
	Activator	46.96 2.25	46.00 1.33	-0.96 2.00	
R_{3X}	Control	19.12 1.95	19.75 1.65	0.63 1.47	
	U-Bugel	23.28 1.24	22.64 1.24	-0.64 0.68	
	Activator	25.64 1.82	24.75 1.66	-0.89 1.51	
R_{4X}	Control	21.31 3.60	21.21 3.04	-0.10 1.97	
	U-Bugel	27.33 2.03	26.58 2.40	-0.75 1.38	
	Activator	33.07 3.09	30.68 2.75	-2.39 3.37	
(PK_X)-(AK_X)	Control	10.81 2.62	11.57 2.81	0.77 0.19	
	U-Bugel	11.04 2.60	10.31 2.43	-0.74 0.17	
	Activator	12.09 3.23	11.64 3.11	-0.45 0.12	

*P<0.05 **P<0.01

Analysis of variance applied to the initial and final (control and treatment) differences revealed no statistically significant differences between the groups (Table 9).

Table 4 Mean and standard deviations of initial, final and control phases regarding (1;2) reference system

Parameter	Group	Initial $X \pm S_x$	Final $X \pm S_x$	Difference $D \pm S_D$	Paired t test
PK_1	Control	18.34 1.40	18.19 1.19	-0.15 0.81	
	U-Bugel	16.15 1.00	16.64 1.12	0.49 1.06	
	Activator	31.14 1.63	14.77 1.36	1.63 1.18	
SK_1	Control	12.19 1.55	12.25 1.36	0.06 1.73	
	U-Bugel	9.86 1.10	10.53 1.19	0.67 1.15	
	Activator	6.29 1.73	7.96 1.28	1.68 1.31	
AK_1	Control	7.59 1.39	6.87 1.24	-0.72 0.78	
	U-Bugel	4.57 0.96	4.90 1.00	0.33 0.75	
	Activator	1.48 1.71	3.02 1.36	1.54 1.27	
Ar_1	Control	17.62 1.42	62.88 1.17	-0.74 0.76	
	U-Bugel	14.71 0.80	15.13 0.87	0.41 0.70	
	Activator	12.36 1.50	13.96 1.12	1.61 1.16	
C_1	Control	11.81 1.41	11.04 1.14	-0.77 0.74	
	U-Bugel	8.64 0.68	9.47 0.86	0.83 0.80	
	Activator	6.63 1.44	8.09 1.12	1.46 1.07	
R_{11}	Control	-15.32 0.53	-14.53 0.94	0.79 0.69	
	U-Bugel	-15.58 0.50	-15.58 0.54	0.00 0.30	
	Activator	-16.11 0.56	-16.14 0.55	-0.03 0.52	
R_{21}	Control	13.06 0.73	14.31 0.54	1.25 0.57	*
	U-Bugel	13.29 0.36	12.76 0.57	-0.53 0.51	
	Activator	12.89 0.56	13.64 0.52	0.75 0.49	
R_{31}	Control	-5.09 0.78	-5.78 0.91	-0.69 0.69	
	U-Bugel	-6.38 0.64	-6.61 0.90	-0.23 0.88	
	Activator	-8.11 0.92	-7.98 0.54	0.13 1.03	
R_{41}	Control	-2.93 1.37	-4.71 1.03	-1.78 0.81	*
	U-Bugel	-2.39 0.74	-2.35 0.99	0.04 0.71	
	Activator	-1.55 1.01	-1.82 1.50	-0.27 1.66	
(PK_1)-(AK_1)	Control	10.75 2.61	11.32 2.75	0.57 0.14	
	U-Bugel	11.58 2.73	11.74 2.77	0.15 0.04	
	Activator	11.59 3.10	11.75 3.14	0.16 0.04	

*P<0.05 **P<0.01

AK1, AR1 and C1 parameters were significantly different ($P < 0.01$) as a result of the difference between the control group and the treatment groups (Table 10).

Table 5 Means and standard deviations of skeletal clasification parameters and paired *t*-test

Parameter	Group	Initial $X \pm S_x$	Final $X \pm S_x$	Difference $D \pm S_D$	Paired t test
GoGn/SN	Control	31.18 0.95	29.74 1.04	-1.44 0.35	**
	U-Bugel	34.83 1.45	34.19 1.47	-0.66 0.15	*
	Activator	35.07 1.39	34.68 1.44	-0.39 0.15	
ANB	Control	4.41 0.50	4.29 0.48	-0.12 0.03	
	U-Bugel	6.06 0.36	4.07 0.56	-1.99 0.47	**
	Activator	5.89 0.61	4.45 0.56	-1.45 0.39	**

*P<0.05 **P<0.01

Table 6 Means and standard deviations of angular measurements and Duncan test.

	Groups	Control I	U-Bügel II	Activator III	Duncan test			
Parameter		Initial $X \pm S_x$	Final $X \pm S_x$	Difference $X \pm S_x$	F	I-II	II-III	I-III
GoGn/SN	Initial	31.18 0.95	34.83 1.45	35.07 1.39	-	-	-	-
	Final	29.74 1.04	34.19 1.47	34.68 1.44	*	*	-	*
	Difference	-1.44 0.35	-0.66 0.15	-0.39 0.15	-	-	-	-
ANB	Initial	4.41 0.50	6.06 0.36	5.89 0.61	*	*	-	-
	Final	4.29 0.48	6.07 0.56	4.45 0.56	-	-	-	-
	Difference	-0.12 0.03	-1.99 0.47	-1.45 0.39	**	**	**	**

*P<0.05 **P<0.01

Discussion

It has been stated that the mandibular growth model might be connected to the condylar growth direction and the variations in the ramal inclination (22,25,26). From this point of view, the effects of functional orthopaedic treatment using activator appliances was evaluated by using condylar measurements, as the condyle has the ability to respond to mechanical stimuli. Functional appliances may increase growth rate of the mandible in the sagittal and vertical directions, but cannot influence the genetic pattern (5,12,27,28). Therefore, the final dimensions of mandible will be the same regardless of treatment, but condylar cartilage and therefore mandibular growth direction might be influenced by using functional treatment appliances.

Table 7 Initial data on X axis

Parameter	Control I	U-Bügel II	Activator III	Duncan test			
Initial	X ± S_x	X ±S_x	X ± S_x	F	I-II	II-III	I-III
PKx	42.85 1.25	45.88 1.11	46.70 1.10				
SKx	36.40 1.99	40.08 1.06	40.34 1.15	*	*	-	*
AKx	32.03 1.19	34.31 1.07	35.34 1.13				
Arx	41.53 1.53	44.22 1.20	46.41 5.39				
Cx	36.62 1.58	38.38 1.21	40.79 1.41				
R1x	8.69 2.01	13.90 1.22	17.96 2.58	**	-	-	**
R2x	37.96 1.96	43.13 1.42	46.96 2.25	*	-	-	*
R3x	19.12 1.95	23.28 1.24	25.64 1.82	*	-	-	*
R4x	21.31 3.60	27.33 2.03	33.07 3.09	*	-	-	*
(PKx)-(Akx)	10.81 2.62	11.04 2.60	12.09 3.23				

*P<0.05 **P<0.01

Table 8 Final data on X axis

Parameter	Control I	U-Bügel II	Activator III	Duncan test			
Initial	X ± S_x	X ±S_x	X ± S_x	F	I-II	II-III	I-III
PKx	43.93 1.31	44.72 1.35	47.20 1.22				
SKx	38.00 1.21	39.32 1.24	40.38 1.24				
AKx	32.35 1.27	34.31 1.31	35.55 1.18				
Arx	42.69 1.70	43.92 1.37	46.38 1.19				
Cx	36.71 1.36	38.89 1.37	40.70 1.27				
R1x	10.50 0.11	13.58 1.42	16.34 1.52	*	-	-	*
R2x	39.79 1.84	42.38 1.59	46.00 1.33	*	-	-	*
R3x	19.75 1.69	22.64 1.24	24.75-1.66				
R4x	21.21 3.04	26.58 2.40	30.98 2.75				
(PKx)-(Akx)	11.75 2.89	10.31 2.43	11.64 3.11				

*P<0.05 **P<0.01

Some studies have been conducted where condylar and mandibular positions on lateral cephalograms were determined (27,29,30). In contrast, Moore et al. stated that the reliability of the condylion point on the cephalograms, taken at the centric occlusion, was sufficient for clinical studies (30).

Table 3 shows that there were no statistically significant differences between the initial and final parameter values. Hence, according to the [1;2] coordinate system, R21 and R41 indirect measurements were found different from the control group (Table 4) showing that posterior and inferior borders of the mandible were distant from the Xi point as a result of spontaneous growth. In other words, at the angulus mandible a resorbtion occurred close to the ramus mandibula whereas apposition occurred at region close to angulus mandible. These variations in the control group may be explained by remodelling (31).

The difference of R21 and R41 (Table 4) was not seen in the treatment groups and suggests that functional treatments might be effective on condyle growth in the sagittal direction. Findings of skeletal classification parameters, ANB and GoGn/SN angles, are shown in Tables V and VI. A similar reduction of these angles was found by Schädlbauer (32) and Jakobsson (33). The difference of SKx in Table VII may be related to the control group, however there were no statistically significant differences in SKx measurement after treatment.

Evaluation of initial treatment and control values regarding the [1;2] coordinate system reveals that the direct condylar measurements (PK, SK, AK, Ar and C) and indirect R3 parameter show significant differences between the groups (Table 10). The cause of these differences arises from the difference between the control and the activator groups as revealed by the Duncan test. However, the normal development of the facial skeleton should also be considered in explaining the differences between the groups. Postero-inferior translation of the fossa glenoidalis, the antero-inferior translation of the nasomaxillary complex, the vertical alveolar development of maxilla and the mandible should be compensated by only mandibular condylar development. If the condyle could not compensate for the aforementioned growth,

Table 9 Initial and final differences on X axis

Parameter	Control I	U-Bügel II	Activator III	Duncan test			
Initial	X ± S_x	X ±S_x	X ± S_x	F	I-II	II-III	I-III
PKx	1.07 0.99	-1.15 1.00	0.50 0.92				
SKx	1.60 1.21	-0.76 0.79	0.04 1.29				
AKx	0.32 0.97	0.00 0.58	0.21 1.29				
Arx	1.16 0.84	0.31 0.84	-0.04 1.26				
Cx	0.09 1.35	0.51 0.67	-0.09 1.26				
R1x	1.81 1.51	-0.32 0.97	-1.63 1.88				
R2x	1.84 1.25	-0.75 0.85	-0.96 2.00				
R3x	0.63 1.47	-0.64 0.68	-0.89 1.51				
R4x	-0.10 1.97	-0.75 1.38	-2.39 3.37				
(PKx)-(AKx)	0.77 0.19	-0.74 0.17	-0.45 0.12				

*P<0.05 **P<0.01

Table 10 Initial data on 1 axis

Parameter	Control I	U-Bügel II	Activator III	Duncan test			
Initial	X ± S_x	X ±S_x	X ± S_x	F	I-II	II-III	I-III
PK1	18.34 1.40	16.15 1.00	13.14 1.63	*			*
SK1	12.19 1.55	9.86 1.00	6.27 1.73	*			*
AK1	7.59 1.39	4.57 0.95	1.48 1.71	**			**
Ar1	17.62 1.42	14.71 0.80	12.36 1.50	**			**
C1	11.81 1.41	8.64 0.68	6.63 1.44	**			**
R11	-15.32 0.53	-15.58 0.49	-16.110.56				
R21	13.06 0.73	13.29 0.36	12.89 0.56				
R31	-5.09 0.78	-6.38 0.64	-8.11 0.92	*			*
R41	-2.93 1.37	-2.39 0.74	-1.55 1.01				
(PK1)-(AK1)	10.75 2.61	11.58 2.73	11.59 3.10				

*P<0.05 **P<0.01

then Class II anomalies occur (34). The material of the current study includes Class II cases with insufficient condylar growth. Therefore, the differences between the groups in terms of growth in the sagittal direction might be considered normal. Initial and final differences were not statistically significant between the groups and this finding suggests that functional treatments may influence the condyle position in the sagittal direction.

Conclusion

In the current study, Class II/div.1 anomalies were corrected and overjet was eliminated by using the functional treatment method via activator appliances. Mandibular condyle growth showed no statistically significant differences in the sagittal direction. However, superior condyle (SK) growth was found statistically different between the pre-treatment and control groups, whereas this difference was not observed following the functional treatment. This leads to the conclusion that condylar adaptation occurs by activator appliances regarding the superior condyle. Therefore, skeletal changes can be achieved by activators in the correction of Class II/div.1 anomalies and the functional treatment concept can be considered as an effective treatment tool for this kind of malocclusions considering treatment prognosis as well as post-treatment stability.

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