

# An evaluation of condylar and ramal vertical asymmetry in adolescents with unilateral and bilateral posterior crossbite using cone beam computed tomography (CBCT)

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*Aims:* The primary purpose was to evaluate condylar and ramal vertical asymmetry in adolescent patients displaying unilateral posterior (UCB) and bilateral posterior crossbite (BCB) malocclusions. A secondary aim was to compare the findings with a matched control group exhibiting normal occlusion (CG) using cone beam computed tomography (CBCT).

*Material and methods:* The study groups consisted of (1) 30 patients (Mean age:  $14.49 \pm 1.91$  years) with a UCB, (2) 29 patients (Mean age:  $14.57 \pm 1.84$  years) with a BCB, and (3) 36 patients (Mean age:  $14.24 \pm 2.42$  years) as a matched control group (CG). Condylar, ramal, condylar-plus-ramal height and index measurements were performed using CBCT images following the method of Habets et al. A paired *t*-test was performed for side comparison in each group. One-way ANOVA (Analysis of Variance) was used to determine statistically-significant differences between the groups for asymmetry index measurements and Tukey's HSD test was employed for individual group differences.

*Results:* There was no statistically significant difference in condylar height (CH), ramal height (RH), and condylar plus ramal height (CH + RH) measurements between the right and left sides of the UCB group and CG, except for the RH in the BCB group ( $p = 0.045$ ). Tukey's HSD test showed that the ramal asymmetry index (RAI) and the condylar plus the ramal asymmetry index (CRAI) were statistically significantly different between the UCB and BCB groups ( $p = 0.035$  and  $p = 0.015$ , respectively).

*Conclusions:* Although the condylar asymmetry index (CAI) values were found to be high in the groups of UCB ( $13.84 \pm 11.33$ ), BCB ( $9.38 \pm 8.56$ ), and CG ( $10.58 \pm 9.48$ ), the comparisons amongst the groups were not statistically significant. The asymmetry between the UCB and BCB groups was observed for RAI and CRAI values, rather than CAI values.

(Aust Orthod J 2014; 1: 11-18)

Received for publication: June 2013

Accepted: February 2014

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## Introduction

A posterior crossbite is a relatively common occlusal problem described as a transverse arch discrepancy.<sup>1-3</sup> Dental and skeletal factors affect the development of a posterior crossbite,<sup>4</sup> of which the most common type is seen unilaterally. The UCB can be distinguished by a functional shift of the mandible toward the affected

side,<sup>3,5</sup> and associated and promoted by asymmetrical muscle function.<sup>6</sup> In addition, it is known that narrowing of the maxillary dental arch and alveolar bone might be the result of abnormal function such as mouth breathing, thumb-sucking habits, aberrant perioral muscle activity and premature primary tooth loss.<sup>7-9</sup> The perseverance of deviant functions

**Table 1.** Inclusion criteria for sample selection.

Control group (CG)	Unilateral crossbite (UCB) group	Bilateral crossbite (BCB) group
Skeletal Class I relationship	Skeletal Class I relationship with unilateral posterior crossbites involving at least two posterior teeth in crossbite	Skeletal Class I relationship with at least two teeth in reverse occlusion in the posterior teeth on both sides
Mesiodivergent face	Mesiodivergent face	Mesiodivergent face
No history of trauma or previous orthodontic treatment, or maxillofacial surgery	No history of trauma or previous orthodontic treatment, or maxillofacial surgery	No history of trauma or previous orthodontic treatment, or maxillofacial surgery
No signs or symptoms of temporomandibular disorder	No signs or symptoms of temporomandibular disorder	No signs or symptoms of temporomandibular disorder
No significant medical history, systemic disease, or neuromuscular deformities	No significant medical history, systemic disease, or neuromuscular deformities	No significant medical history, systemic disease, or neuromuscular deformities
No functional deviation of the mandible	Functional deviation of the mandible	–

may cause changes in tooth position, bony support and possibly alterations in the development of the temporomandibular joint.<sup>9</sup> The asymmetrical function of the stomatognathic system might be due to asynchronous development in the two sides of the mandible. As one of the most sensitive structures to occlusal change,<sup>10</sup> the condyle has been reported to be malpositioned in the glenoid fossae of children and adolescents with UCB.<sup>11-13</sup>

Mandibular asymmetry has long been assessed using two-dimensional (2D) radiographs<sup>14-16</sup> but may now be investigated using three-dimensional (3D) imaging provided by computed tomography (CT) and CBCT.<sup>17</sup> As asymmetry of the facial bones is most readily diagnosed from the frontal aspect, Habets et al. introduced a method to determine the existence of vertical asymmetries between the mandibular condyles and the ramus.<sup>18,19</sup> This method has been used to determine condylar asymmetry in temporomandibular-disorder patients,<sup>18</sup> in different skeletal patterns,<sup>20-22</sup> cleft lip and palate patients,<sup>23</sup> and in early bilateral first molar extraction cases.<sup>24</sup> However, few condylar asymmetry studies have been performed on patients with unilateral<sup>25,26</sup> and bilateral<sup>26,27</sup> posterior crossbite.

All previous studies examining vertical condylar asymmetry have been performed using panoramic radiographs.<sup>28</sup> The plane films allow scanning of maxillary and mandibular anatomy at a relatively low cost and low radiation exposure, and have been commonly applied in dental research and clinical practice.<sup>28</sup> Nevertheless, panoramic radiographs have

disadvantages, related to inconsistent magnification, image distortion, and a narrow image layer.<sup>29</sup> In addition, it has been reported that mandibular vertical measurements for lateral and anteroposterior dimensions can be affected by head positioning during panoramic radiography.<sup>29</sup>

Contemporary 3D technology makes it feasible to achieve true (1:1 in size) images devoid of magnification.<sup>17</sup> However, CT has the disadvantage of high radiation exposure and relatively high costs, which limit its use in daily dental practice; Nevertheless, CBCT has the advantages of relatively low radiation dose and low costs.<sup>30</sup>

Although studies<sup>20-27,31</sup> assessing condylar asymmetry have increased in the past years, no study has compared condylar and ramal vertical asymmetry in UCB and BCB patients. Therefore, the aims of this study were to investigate condylar and ramal vertical asymmetry in patients presenting with UCB and BCB malocclusions using CBCT, and to subsequently compare the asymmetry values with a matched group possessing normal occlusion by employing the method described by Habets et al.<sup>18,19</sup>

## Materials and methods

CBCT scans were obtained from the archives of the Oral and Maxillofacial Radiology of Faculty of Dentistry, Erciyes University, Kayseri, Turkey. CBCT scans of patients were taken for diagnostic reasons related to previous dental treatment. The patients were therefore not exposed to any additional radiation for



Figure 1. Measuring method according to Habets et al.<sup>18,19</sup>



Figure 2. CBCT image of a patient with UCB.



Figure 3. CBCT image of a patient with BCB.

the present study but informed consent was obtained from the patients' parents to enable the use of the data for scientific purposes.

The patients were divided into three groups according to the following inclusion criteria (Table I): (1) 30 patients (15 males, 15 females; Mean age:  $14.49 \pm 1.91$  years) with UCB, (2) 29 patients (12 males, 17

females; Mean age:  $14.57 \pm 1.84$  years) with BCB, and (3) 36 patients (11 males, 25 females; Mean age:  $14.24 \pm 2.42$  years) as a matched CG. A buccal crossbite was defined as involving at least two posterior teeth from canine to second molar. The patient's chronological age, gender, ANB, and SN-GoGn angles (measured by means of lateral cephalometric films obtained from CBCT images) were recorded.

**Table II.** Means and standard deviations of the chronological ages, ANB and SN-GoMe angles in each group.

Group	Gender	Age (years)	ANB (°)	SN-GoMe (°)	p1	p2
Unilateral posterior crossbite (UCB)	Male (N = 15)	13.95 ± 1.30	2.52 ± 2.11	33.07 ± 3.49	NS	NS
	Female (N = 15)	15.03 ± 2.29	2.62 ± 2.28	34.57 ± 5.56		
	Total (N = 30)	14.49 ± 1.91	2.57 ± 2.16	33.82 ± 4.62		
Bilateral posterior crossbite (BCB)	Male (N = 12)	14.71 ± 1.78	2.32 ± 1.54	34.18 ± 5.27	NS	NS
	Female (N = 17)	14.47 ± 1.94	3.07 ± 1.86	38.11 ± 5.54		
	Total (N = 29)	14.57 ± 1.84	2.76 ± 1.75	36.48 ± 5.68		
Normal occlusion (CG)	Male (N = 11)	13.50 ± 2.38	2.56 ± 1.14	31.93 ± 7.88	NS	NS
	Female (N = 25)	14.56 ± 2.41	3.01 ± 1.58	35.39 ± 6.67		
	Total (N = 36)	14.24 ± 2.42	2.87 ± 1.46	34.33 ± 7.13		

p1, results of Student's *t* test comparing the genders; p2, results of one-way ANOVA test comparing the groups; NS, not significant

**Table III.** Descriptive statistics and comparisons of mandibular asymmetry indexes among groups according to gender.

Group	Variable (%)	Male (N = 38)		Female (N = 57)		p
		Mean	SD	Mean	SD	
Unilateral crossbite (N = 30) (M/F, 15/15)	CAI	14.65	13.42	13.03	9.19	.702
	RAI	2.98	1.39	3.69	2.04	.273
	CRAI	2.56	1.65	4.11	2.28	<b>.042</b>
Bilateral crossbite (N = 29) (M/F, 12/17)	CAI	6.62	4.29	11.33	10.28	.147
	RAI	2.14	2.23	2.32	1.50	.800
	CRAI	1.74	2.18	2.07	1.56	.639
Normal occlusion (N = 36) (M/F, 11/25)	CAI	10.68	11.13	10.54	8.91	.968
	RAI	2.58	1.18	2.58	1.51	.979
	CRAI	2.05	1.68	2.46	1.83	.528

CAI, condylar asymmetry index; RAI, ramal asymmetry index; CRAI, condylar-plus-ramal asymmetry index; M/F, male/female; SD, standard deviation; p, results of Student's *t* test comparing the gender difference; significant value in bold

All CBCT images were obtained in the supine position (NewTom 5G, QR VRN, Italy) using a scanning time of 18 seconds, an exposure time of 3.6 seconds, a collimation height of 13 cm, and a voxel size of 0.3 mm.<sup>3</sup> Digital Imaging and Communications in Medicine (DICOM) files obtained from the CBCT scans were reconstructed using Simplant software, version 13.0 (Materialise NV, Leuven, Belgium). One researcher conducted all measurements.

The most posterior bilateral points on the condyle and ramus were marked as X and Y (Figure 1). A line was drawn passing through points X and Y and termed the A-line. A second line was drawn from the most superior point of the condylar images, perpendicular

to the A-line, and was termed the B-line. The intersection of the A- and B-line was called point Z. The distances between points X and Z were measured as condylar height (CH). Similarly, the distances between points X and Y, and that between points Z and Y, were measured as ramus height (RH) and condylar plus ramus heights (CH + RH), respectively (Figure 1). All asymmetry indices of the condylar (CAI), ramal (RAI), and condylar-plus-ramal (CRAI) were calculated using the following formula developed by Habets et al.<sup>18</sup>

$$\text{Asymmetry index: } \left| \frac{\text{Right} - \text{Left}}{\text{Right} + \text{Left}} \right| \times 100$$

**Table IV.** Statistical side comparisons of the three groups.

Variable	Unilateral crossbite (UCB)			Bilateral crossbite (BCB)			Normal occlusion (CG)		
	Normal side	Cross side	<i>p</i>	Right side	Left side	<i>p</i>	Right side	Left side	<i>p</i>
CH	4.50 ± 1.31	4.53 ± 1.19	.917	3.86 ± 0.83	3.94 ± 0.85	.683	4.28 ± 0.92	4.28 ± 0.90	1.000
RH	43.70 ± 4.47	43.73 ± 4.28	.978	44.67 ± 4.30	43.74 ± 4.21	<b>.045</b>	43.80 ± 5.14	43.26 ± 5.15	.219
CH + RH	48.21 ± 4.81	48.26 ± 4.63	.947	48.53 ± 4.56	47.68 ± 4.45	.067	48.08 ± 5.58	47.54 ± 5.63	.251

CH, condylar height; RH, ramal height; CH + RH, condylar-plus-ramal height; test, *p*, results of paired samples *t*-test

**Table V.** Comparisons of mandibular asymmetry index values among the groups.

Asymmetry index	Group	N	Mean (%)	<i>p</i>	UCB - BCB	UCB - CG	BCB - CG
CAI	Unilateral crossbite (UCB)	30	13.84 ± 11.33	.199	NS	NS	NS
	Bilateral crossbite (BCB)	29	9.38 ± 8.56				
	Normal occlusion (CG)	36	10.58 ± 9.48				
RAI	Unilateral crossbite (UCB)	30	3.34 ± 1.76	<b>.037</b>	<b>.035</b>	NS	NS
	Bilateral crossbite (BCB)	29	2.25 ± 1.80				
	Normal occlusion (CG)	36	2.57 ± 1.40				
CRAI	Unilateral crossbite (UCB)	30	3.33 ± 2.11	<b>.016</b>	<b>.015</b>	NS	NS
	Bilateral crossbite (BCB)	29	1.93 ± 1.81				
	Normal occlusion (CG)	36	2.34 ± 1.77				

CAI, condylar asymmetry index; RAI, ramal asymmetry index; CRAI, condylar-plus-ramal asymmetry index; *p*, results of one-way ANOVA test comparing three groups; NS, not significant; significant values in bold

### Statistical analysis

All statistical analyses were performed using the SPSS software package for Windows (version 15.0, SPSS, IL, USA). A value of  $p < 0.05$  was considered as statistically significant.

Three weeks after the initial measurements, 25 randomly selected CBCT images were retraced and re-measured by the same author. The method error was calculated using Dahlberg's<sup>32</sup> formula and shown to be within acceptable limits. In addition, the difference between the two tracings was tested for significance using a paired *t*-test, and no significant difference was found ( $p > 0.05$ ), confirming the reliability of the measurements.

Descriptive data also included the patient's chronological age, gender, ANB, and SN-GoGn angles. The normality test of Shapiro-Wilks and Levene's variance homogeneity test were applied to the data. The data were normally distributed. Therefore, the comparison among the groups and

genders was analysed with parametric tests. Student's *t*-test and one-way ANOVA test were used to compare descriptive data between the genders and among the groups, respectively. The Student's *t*-test was used to determine the gender difference according to the asymmetry indices. A paired *t*-test was used to determine the potential differences between the sides for CH, RH, and CH + RH measurements for each group. An ANOVA test was used to determine any statistically significant differences among the groups for CAI, RAI, and CRAI measurements, and Tukey's HSD test was employed for the comparison of the individual differences.

### Results

The demographic features of all patients included in the present study are shown in Table II. The results of the Student's *t*-test, comparing the genders, and one-way ANOVA test, comparing the groups' chronological age, ANB, and SN-GoMe angles,

showed no statistically significant differences. This result indicates that subjects in all groups had a similar growth pattern in the vertical and sagittal dimensions and were well aged matched.

The descriptive mandibular asymmetry indices for male and female patients were calculated separately for all groups, and the comparison between the genders is shown in Table III. The results of the Student's *t*-tests revealed that there were no statistically significant differences, except for the CRAI index in the UCB group. As the difference was negligible ( $p = 0.042$ ), the data for both sexes were pooled for further statistical analyses.

Means, standard deviations, and statistical results of the tests comparing the measurements of the normal and crossbite sides in the UCB group, and the left and right sides in the BCB group and CG, are shown in Table IV. There was no statistically significant difference between the right and left sides in CH, RH, and CH + RH measurements of the UCB group and CG. However, there was a statistically significant difference between the right and left sides for the RH measurements in the BCB groups with approximately a 1.07 mm discrepancy ( $p = 0.045$ ).

The results of the ANOVA test revealed that CAI measurements were not statistically different among UCB, BCB, and CG. However, RAI and CRAI measurements among the groups were found to be statistically significant ( $p = 0.037$  and  $p = 0.016$ , respectively). Therefore, further post hoc tests were performed to determine individual differences. Tukey's HSD test showed that RAI and CRAI values were statistically and significantly different among the UCB and BCB groups ( $p = 0.035$  and  $p = 0.015$ , respectively); the RAI and CRAI values in the UCB group were  $3.34 \pm 1.76$  and  $3.33 \pm 2.11\%$ , respectively, while those in the BCB group were  $2.25 \pm 1.80$  and  $1.93 \pm 1.81\%$ , respectively (Table V). Examples of the patients' CBCT images with UCB and BCB are shown in Figures 2 and 3.

## Discussion

Although panoramic radiographic images of anatomical structures in the vertical and horizontal planes could be magnified,<sup>19,33</sup> the radiographs have often been used in condylar<sup>20-27,34</sup> and mandibular<sup>35,36</sup> asymmetry studies. Computerised tomography is the accepted standard for the examination of asymmetries without

magnification,<sup>17,37</sup> although radiation exposure and cost are concerning issues. However, CBCTs provide a relatively low radiation dose with low costs. Therefore in the present study, existing CBCT images were used to assess condylar and ramal vertical asymmetry, and considered the first to evaluate possible vertical discrepancies in patients exhibiting UCB and BCB by employing a previously-developed method.<sup>18,19</sup>

In earlier studies on the use of panoramic radiographs, Kilic et al.<sup>27</sup> stated that CH, RH, and CH + RH on the crossbite side were less than those on the non-crossbite side. Kiki et al.<sup>25</sup> reported that the differences between the right and left sides in the BCB group were greater than those in the normal occlusion group. However, Kiki et al.<sup>25</sup> and Uysal et al.<sup>26</sup> found no statistically significant differences between the right and left sides in both the BCB and a control group. In the present study, it was found that CH, RH, and CH + RH in all groups were similar on the right and left sides, without statistically significant side differences, except for the RH in the BCB group which displayed approximately 1.07 mm difference.

Kilic et al.<sup>27</sup> concluded that patients with UCB had more asymmetric condyles than those with normal occlusions and Kiki et al.<sup>25</sup> reported that greater condylar asymmetry was found in BCB groups compared with a group possessing normal occlusions. However, in contradistinction,<sup>25,27</sup> Uysal et al.<sup>26</sup> found no statistically significant differences in mandibular asymmetry determined separately with respect to CAI, RAI, and CRAI after multiple comparisons made between the UCB, BCB and control groups. In the present study, no statistically significant differences were found in CAI values. However, it was observed that RAI and CRAI indices were statistically different between the UCB and BCB groups. The RAI and CRAI parameters increased in the UCB groups compared with the CG, while RAI and CRAI decreased in the BCB groups compared with the CG. This may be explained by the use of panoramic radiographs for the evaluation of vertical mandibular asymmetry because vertical magnification in panoramic radiographs can be inconsistent.

According to Habets et al.,<sup>19</sup> a 3% index ratio can result from a 1 cm change in head position while a panoramic radiograph is being taken. Because head position is not a criterion when using CBCT, the present study tested the 3% index ratio and found that the CAI values in all groups (CG:  $10.58 \pm 9.48$ ,

UCB:  $13.84 \pm 11.33$ , and BCB:  $9.38 \pm 8.56$ ) were higher when compared with the 3% threshold value proposed by Habets et al.<sup>19</sup> However, the comparison between groups was not statistically significant. In addition, all patients with or without crossbite were found to have an asymmetric mandible according to the CAI measurements. In agreement with the present findings, Sağlam,<sup>20</sup> Kurt et al.,<sup>23</sup> Halicioğlu et al.,<sup>24</sup> and Uysal et al.<sup>26</sup> found CAI values of  $7.96 \pm 6.73$ ,  $9.95 \pm 10.42$ ,  $7.04 \pm 6.79$ , and  $7.57 \pm 8.39\%$  in the normal occlusion groups, respectively. These high CAI values could be detected with or without any related malocclusions. Therefore, it is beneficial that investigators, examining condylar asymmetry, incorporate the 3% threshold value proposed by Habets et al.<sup>19</sup>

Sağlam<sup>20</sup> asserted that CRAI measurements were significantly affected by gender. However, previous contradictory studies<sup>18,24-26,34</sup> found no statistically significant differences in asymmetry indices between the genders. Similarly, the present study observed that the asymmetry indices were not affected by gender in the control and BCB groups. However, the CRAI measurements were related to gender in the UCB groups. Female patients with UCB had higher CRAI values ( $4.11 \pm 2.28\%$ ) than male patients with UCB ( $2.56 \pm 1.65\%$ ) ( $p = 0.042$ ).

A limitation of the present study was the small patient samples, when compared with previous studies, which assessed condylar asymmetry. The effects of age on condylar asymmetry in patients with UCB and BCB were not assessed in the present study due to the age matching of the groups. A previously published study<sup>38</sup> showed that age did not affect facial asymmetry in patients with a unilateral functional crossbite in the primary, early and late mixed dentition phases. However, no studies have been performed to evaluate the relationship of age and condylar asymmetry, which therefore might be the subject of future studies.

## Conclusions

CAI values were significantly higher in all groups when compared with the 3% threshold value proposed by Habets et al.<sup>18,19</sup> However, comparisons between the groups were not statistically significant. RAI and CRAI values were statistically different between UCB and BCB groups. As a result of these evaluations, it

can be proposed that patients with UCB had higher CAI values. Further investigations with larger sample sizes, evaluated in three dimensions and assessing occlusal asymmetry, are needed to confirm the results of the present study.

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## References

1. Sandikçiöğlü M, Hazar S. Skeletal and dental changes after maxillary expansion in the mixed dentition. *Am J Orthod Dentofacial Orthop* 1997;111:321-7.
2. Halicioğlu K, Kiki A, Yavuz I. Maxillary expansion with the memory screw: a preliminary investigation. *Korean J Orthod* 2012;42:73-9.
3. Kennedy DB, Osepchook M. Unilateral posterior crossbite with mandibular shift: a review. *J Can Dent Assoc* 2005;71:569-73.
4. Allen D, Rebellato J, Sheats R, Ceron AM. Skeletal and dental contributions to posterior crossbites. *Angle Orthod* 2003 73:515-24.
5. Thilander B, Wahlund S, Lennartsson B. The effect of early interceptive treatment in children with posterior cross-bite. *Eur J Orthod* 1984 6:25-34.
6. Ferrario VF, Sforza C, Serrao G. The influence of crossbite on the coordinated electromyographic activity of human masticatory muscles during mastication. *J Oral Rehabil* 1999;26:575-81.
7. McNamara JA. Influence of respiratory pattern on craniofacial growth. *Angle Orthod* 1981 51:269-300.
8. Saccomanno S, Antonini G, D'Alatri L, D'Angelantonio M, Fiorita A, Deli R. Causal relationship between malocclusion and oral muscles dysfunction: a model of approach. *Eur J Paediatr Dent* 2012;13:321-3.
9. Graber TM. *Orthodontics-Principles and Practice*. Philadelphia, Pa: WB Saunders Co 1967;470:674-5.
10. Pirttiniemi P, Kantomaa T, Salo L, Tuominen M. Effect of reduced articular function on deposition of type I and type II collagens in the mandibular condylar cartilage of the rat. *Arch Oral Biol* 1996;41:127-31.
11. Lam PH, Sadowsky C, Omerza F. Mandibular asymmetry and condylar position in children with unilateral posterior crossbite. *Am J Orthod Dentofacial Orthop* 1999;115:569-75.
12. Hesse KL, Artun J, Joondoph DR, Kennedy DB. Changes in condylar position and occlusion associated with maxillary expansion for correction of functional unilateral posterior crossbite. *Am J Orthod Dentofacial Orthop* 1997 111:410-8.
13. Myers DR, Barenie JT, Bell RA, Williamson EH. Condylar position in children with functional posterior crossbites: before and after crossbite correction. *Pediatr Dent* 1980;2:190-4.
14. Çağlaroğlu M, İlu M, Kilic N, Erdem A. Effects of early unilateral first molar extraction on skeletal asymmetry. *Am J Orthod Dentofacial Orthop* 2008;134:270-5.

15. Laspos CB, Kyrkanides S, Tallents RH, Moss ME, Subtelny JD. Mandibular asymmetry in noncleft and unilateral cleft lip and palate individuals. *Cleft Palate Craniofac J* 1997;34:410-16.
16. Liukkonen M, Sillanmäki L, Peltomäki T. Mandibular asymmetry in healthy children. *Acta Odontol Scand* 2005;63:168-72.
17. Veli I, Uysal T, Ozer T, Ucar FI, Eruz M. Mandibular asymmetry in unilateral and bilateral posterior crossbite patients using cone-beam computed tomography. *Angle Orthod* 2011;81:966-74.
18. Habets LL, Bezuur JN, Naeiji M, Hansson TL. The orthopantomogram, an aid in diagnosis of temporomandibular joint problems. II. The vertical symmetry. *J Oral Rehabil* 1988;15:465-71.
19. Habets LL, Bezuur JN, van Ooij CP, Hansson TL. The orthopantomogram, an aid in diagnosis of temporomandibular joint problems. I. The factor of vertical magnification. *J Oral Rehabil* 1987;14:475-80.
20. Sağlam AM. The condylar asymmetry measurements in different skeletal patterns. *J Oral Rehabil* 2003;30:738-42.
21. Miller VJ, Smidt A. Condylar asymmetry and age in patients with an Angle's Class II division 2 malocclusion. *J Oral Rehabil* 1996;23:712-5.
22. Miller VJ, Bodner L. Condylar asymmetry measurements in patients with an Angle's Class III malocclusion. *J Oral Rehabil* 1997;24:247-9.
23. Kurt G, Bayram M, Uysal T, Ozer M. Mandibular asymmetry in cleft lip and palate patients. *Eur J Orthod* 2010;32:19-23.
24. Halicioğlu K, Çelikoglu M, Çağlaroğlu M, Büyük SK, Akkas I, Sekerci AE. Effects of early bilateral mandibular first molar extraction on condylar and ramal vertical asymmetry. *Clin Oral Investig* 2013;17:1557-61.
25. Kiki A, Kiliç N, Oktay H. Condylar asymmetry in bilateral posterior crossbite patients. *Angle Orthod* 2007;77:77-81.
26. Uysal T, Sisman Y, Kurt G, Ramoğlu SI. Condylar and ramal vertical asymmetry in unilateral and bilateral posterior crossbite patients and a normal occlusion sample. *Am J Orthod Dentofacial Orthop* 2009;136:37-43.
27. Kilic N, Kiki A, Oktay H. Condylar asymmetry in unilateral posterior crossbite patients. *Am J Orthod Dentofacial Orthop* 2008;133:382-7.
28. Tugnait A, Clerehugh DV, Hirschmann PN. Survey of radiographic practices for periodontal disease in UK and Irish dental teaching hospitals. *Dentomaxillofac Radiol* 2000;29:376-81.
29. Kitai N, Mukai Y, Murabayashi M, Kawabata A, Washino K, Matsuoka M et al. Measurement accuracy with a new dental panoramic radiographic technique based on tomosynthesis. *Angle Orthod* 2013;83:117-26.
30. Rossini G, Cavallini C, Cassetta M, Galluccio G, Barbato E. Localization of impacted maxillary canines using cone beam computed tomography. Review of the literature. *Ann Stomatol (Roma)* 2012 3:14-18.
31. Celikoglu M, Halicioğlu K, Büyük SK, Sekerci AE, Ucar FI. Condylar and ramal vertical asymmetry in adolescent patients affected by cleft lip and palate using cone beam computed tomography. *Am J Orthod Dentofacial Orthop* 2013;144:691-7.
32. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications 1940.
33. Langland OE, Sippy FH. Anatomic structures as visualized on the orthopantomogram. *Oral Surg Oral Med Oral Pathol* 1968;26:475-84.
34. Sezgin OS, Celenk P, Arici S. Mandibular asymmetry in different occlusion patterns. *Angle Orthod* 2007;77:803-7.
35. Ramirez-Yañez GO, Stewart A, Franken E, Campos K. Prevalence of mandibular asymmetries in growing patients. *Eur J Orthod* 2011;33:236-42.
36. Van Elslande DC, Russett SJ, Major PW, Flores-Mir C. Mandibular asymmetry diagnosis with panoramic imaging. *Am J Orthod Dentofacial Orthop* 2008;134:183-92.
37. Sanders DA, Rigali PH, Neace WP, Uribe F, Nanda R. Skeletal and dental asymmetries in Class II subdivision malocclusions using cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 2010;138:542.e541-520.
38. Primozic J, Perinetti G, Richmond S, Ovsenik M. Three-dimensional evaluation of facial asymmetry in association with unilateral functional crossbite in the primary, early, and late mixed dentition phases. *Angle Orthod* 2013;83:253-8.