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THE RELATIONSHIP BETWEEN THE MANDIBULAR CONDYLE POSITION IN THE SAGITTAL AND FRONTAL PLANES AMONG ADULT FEMALES WITH SKELETAL CLASS I (CEPHALOMETRIC STUDY)

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Abstract. The study included 15 orthodontically untreated adult females aged 17—24 years with skeletal class I, who had not previously undergone orthodontic treatment, with no facial asymmetry and no history of temporomandibular damage nor any clinical signs of it. Postero-anterior and lateral cephalometry revealed in them the presence of various variants of the relationship between the position of the mandibular condyle in the sagittal and frontal planes.

Key words: mandibular condyle position, postero-anterior cephalometric, lateral cephalometric.

ВЗАИМОСВЯЗЬ ПОЛОЖЕНИЯ МЫЩЕЛКОВОГО ОТРОСТКА НИЖНЕЙ ЧЕЛЮСТИ В САГИТТАЛЬНОЙ И ФРОНТАЛЬНОЙ ПЛОСКОСТЯХ У ВЗРОСЛЫХ ЖЕНЩИН СО СКЕЛЕТНЫМ КЛАССОМ I (ЦЕФАЛОМЕТРИЧЕСКОЕ ИССЛЕДОВАНИЕ)

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Аннотация. В исследовании включено 15 женщин в возрасте 17—24 лет со скелетным классом I, ранее не проходивших ортодонтического лечения, не имевших асимметрии лица и признаков поражения височно-нижнечелюстного сустава, в том числе в прошлом. Проведение задне-передней и боковой цефалометрии выявило у них наличие различных вариантов взаимосвязи между положением мыщелка нижней челюсти в сагиттальной и фронтальной плоскостях.

Ключевые слова: положение мыщелка нижней челюсти, задне-передняя цефалометрия, боковая цефалометрия.

Introduction

Anteroposterior skeletal malocclusions are commonly defined by the relationship of the maxilla and mandible to the cranium, where the TMJ's elements playing very important role in the variability morphology of the sagittal and vertical jaws relationship. Furthermore, since the mandible articulates with the cranium, it is paramount that proportionate growth be achieved between anterior and posterior facial heights [2, 3], influencing both sagittal and vertical facial morphology [8–12]. Several cephalometric researches inspected the condylar position in the sagittal plane corresponding to cranial base, orofacial complex [1–3], to the other TMJ's elements, and external auditory meatus [4, 5]. Whereas In the frontal plane, cephalometric researches inspected the most the influence of the condylar position in facial asymmetry patients [6, 7] where the condylar position was the less inspected. However, the literature offers very rich information about the TMJ morphology using 3D techniques [13, 14], which is very costly indeed for the patients in the traditional orthodontics treatment. Consequently, it is important to determinant the possible identifiable mandibular condyle location in both of frontal and sagittal planes using frontal and sagital cephalograms, which is a very common and low coast analyzing utility in the daily orthodontics practices. In the recent study, such determination was performed amongst patients without facial asymmetry, clinical signs or history of temporomandibular joint disorders as well as with first skeletal class. The first skeletal class has almost been the intention of the orthodontics treatment in consideration of harmonic approach as a final objective of the treatment, especially in patients with jaws discrepancy malocclusions. Additionally, according to some 3D methods studies TMJ analysis, the condylar position has its particular relationship against the other anatomical TMJ structures for each skeletal class of jaw discrepancy [15–19]. Furthermore, the abnormalities of mandibular condylar morphology and position increased with age. They were seen more frequently in patients with clinical signs and symptoms of temporomandibular disorders and in patients with loss of teeth [20–22].

Study Objectives. The purpose of the present study was to seek possible relationship between the mandibular condyle position in the sagittal and frontal planes by means of both postero-anterior and lateral cephalograms amongst orthodontically non-treated skeletal class I adult females with no facial asymmetry, no history of temporomandibular joint disorders nor any clinical signs of it.

Materials and methods

Criteria of Subjects selecting: 15 orthodontically untreated adult females with skeletal class I were selected from patients who required both sagital and postero-anterior cephalograms in the Department of Orthodontics and Dentofacial Orthopedics at Tishreen University, then who further cephalometric investigations of the frontal cephalograms reveal no facial asymmetry. The skeletal class was defined on the base of **ANB** angle. Subjects were considered in skeletal class I if the **ANB** angle ranged between 2°± 2°. [19]. Subjects with history of trauma to the dento-facial structures, history of abnormal habits, supernumerary teeth and/ or missing teeth, congenital anomalies, evident signs of syndromes and/or dentoskeletal asymmetries and/or craniofacial malformation were excluded also. Additionally, exclusion clinical criterion also was the clinical signs or history of temporomandibular joint disorders such as TMJ sounds (clicking or crepitation), range and deviation of mouth opening, tenderness to palpation of the joint and the masticatory muscles, and joint or muscle pain during mouth opening and protrusive or lateral mandibular movements. Moreover, exclusion were also the TMD patients who were revealed by the manual functional analysis (MFA) examination technique intended for patients with no history of symptoms according to Baumann and Groot [22, 23]. Should be noted that, only the first part of (MFA) was performed. In first part of (MFA) the loading vector usually determined, (the second part of MFA intended for patients with TMD where the various TMD etiological factors usually investigated [22]). In this study, panoramic radiography has been used as a screening tool to exclude patients with gross bony changes in the condyle as Crow [24] recommended. Patients were also excluded from the study when panoramic radiograph did not reveal the condylar anatomy clearly.

Granting the basic morphology of mandibular condyle is thought to be established early [25]. Particularly, it was indicated that the distance between the glinoid fossa and nasion increases 7.5 mm between 12 and 20 years of age when the landmark Articular is used [26,27]. Additionally, it has been noted that the absence of morphologic variation was much more common in the younger age group. The prevalence of changes in condylar morphology was more in individuals above 40 years (90 %) as compared to those below the age of 40 (64 %) [20]. therefore, the mean age of the selected 15 subjects in current study was 19.1 years, where: (SD) = 2.7 years, (min) =17 years, (max) =24 years.

Sample estimation: to determine the minimum sample size to be statistically significant, a statistical pilot study was applied on 15 subjects (who were selected according to the criteria of selecting this study"s sample). It has been found that descriptive statistics results follow the normal distribution; therefore, determining the minimum sample size to be statistically significant was according to the following formula:

$$n = \frac{Z^2 . \sigma^2}{(e)^2}$$

(N): is the sample size ;.(z): is the value corresponding to a confidence level, estimated at 99 % (Z = 2.58) (i.e. significance level is 0.019), (y): highest Standard Deviation value within all the variables (y = 6.7)

(e): Margin of error (maximum acceptable error in mean estimate) (e=5)

Thus:

$$n = \frac{(2.58)^2 (6.7)^2}{5^2} \approx 11.95$$

According to this statistical pilot study, we determined that to get an exact estimate about the mean of patients' results, and the error in his estimate does not exceed 5 of the mean, with a significance level of 99 % requires a sample size (n) of 11.95 patients as minimum, while the size of this study's sample was 15 Caucasian females.

All sagittal and postero-anterior cephalograms were obtained before any orthodontics treatment has taken place using the same cephalometer in centric occlusion (The standard cephalometer settings were 75 kV, 10 mA, 0,7 second exposure time, with magnification standardized at 10 %). To eliminate rotational errors, ear-rods and nasal rest were used The source–transporionic axis distance was 150 cm and the transporionic axis–film distance 12,5 cm. The subjects were positioned with the transporionic axis and Frankfort plane horizontal to the oor. The films were scanned at 600 dpi and displayed on a at screen personal computer monitor with a pixel size of 0,051 mm, smaller than the 0,1 mm maximum [28].

All measurements on booth postero-anterior (Figure 1) and sagittal cephalograms (Figure 2) were digitized by the researcher under identical conditions using AudaxCeph software (sizes were to the nearest 0,01 mm.

Landmarks, reference planes and measurements on **postero-anterior cephalograms** (fig. 1–2):

1. **Crista Galli point (Cg)**: apex of the Crista Galli, the crista galli is a median ridge of bone that projects from the cribriform plate of the ethmoid bone [29–33].
2. **GWSO(R)**: intersection of the right greater wing of sphenoid and inner cortex of the right supero-lateral orbital rim [33–36].
3. **GWSO(L)**: intersection of left greater wing of sphenoid and the inner cortex of the left supero-lateral orbital rim [33–36].
4. **The point Jugale right (JR)**: The intersection of the lateral contour of the right maxillary alveolar process and the lower contour of the right maxillo zygomatic (Jugal) process of the maxilla [32, 35, 37, 38].
5. **The point Jugale left (JL)**: The intersection of the lateral contour of the left maxillary alveolar process and the lower contour of the left maxillo zygomatic (Jugal) process of the maxilla [32, 35, 37, 38].
6. **Condylar right (CondR)**: most superior point on the right mandibular condyle [29, 33, 39].
7. **Condylar left (CondL)**: most superior point on the left mandibular condyle [29, 33, 39].
8. **Condylion lateral right CoL(R)**: The most lateral point on the right condylar head [38].
9. **Condylion lateral left CoL(L)**: The most lateral point on the left condylar head [38].

10. **Articular Right (ArR)**: The intersection of the connected outline between of the right maxillary tuberosity (starting from the **JR**) and the lateral outline of the right condyle [40, 41].
11. **Articular Left (ArL):** The intersection of the connected outline between of the left maxillary tuberosity (starting from the **JL**) and the lateral outline of the left condyle [40, 41].
12. **GWSO plane**: A line connecting **GWSO(R)** and **GWSO(L)** [41]. Left and right **GWSO** points were used here, since they exhibited the least asymmetry and the least vari-ability structure on the postero-anterior cephalograms [36, 39].
13. **M plane** (Mid Sagittal Reference Plane at Crista Galli). The midfacial line was drawn as a line perpendicular to the line connecting **GWSO(R)** – **GWSO(L)** through Cg [41–43].

The reference **M plane** and **GWSO plane** were used to build the **postero-anterior Cephalometric reference coordinate system** for liner measurements [41–43].

The x, y coordinates of the skeletal landmarks: **(CondR)**, **(CondL)**, **CoL(R)**, **CoL(L)**, **(ArR)**, **(ArL)** (fig. 1) were measured and digitized. Assessment of transverse and vertical frontal facial asymmetry was done by comparing x, y coordinates of the skeletal landmarks in the right side with its analog the left side in relation to the **postero-anterior Cephalometric reference coordinate system**. Furthermore, the x, y coordinates of **(CondR)**, **(CondL)**, **CoL(R)**, **CoL(L)**, **(ArR)**, **(ArL)** were used to describe the position of left and right mandibular condyles in relation to the **postero-anterior Cephalometric reference coordinate system**.

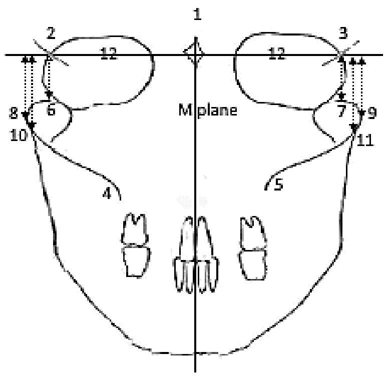

Fig. 1. Reference planes and Landmarks and its (y) coordinates on postero-anterior cephalograms

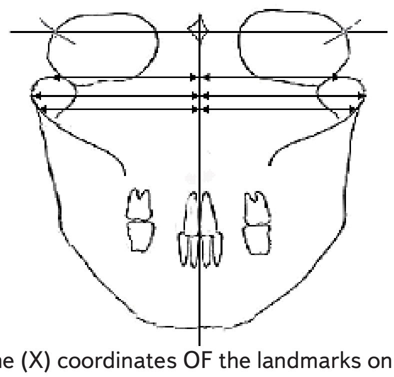

Fig. 2. The (X) coordinates OF the landmarks on postero-anterior cephalograms

*Landmarks, reference planes and measurements on **lateral cephalograms** (fig. 2):*

1. **Sella turcica (S)**. The pituitary fossa of the sphenoid bone (sella-center of sella turcica, determined by inspection).
2. **Nasion (N).** The anterior part of the nasal frontal suture.
3. **Point A (A).** The deepest midline point on the premaxilla between the anterior nasal spine and the upper incisor teeth (subspinale).
4. **Point B (B)**. The deepest midline point on the mandible between the lower incisor and the bony chin point (supramentale).
   ANB angle [43] was used in this study for assessing skeletal jaw relationship in the sagittal plane. The ANB angle is formed with the vertex at Nasion **(N)** and two sides respectively extending to Point **A**, as well as to Point **B**. In effect, the **ANB** angle is the difference between the **SNA** and the **SNB** angles, which usually used to assess skeletal positions of the upper and the lower jaws, respectively [9, 44–47]. **ANB** angle still an accepted method of assessing the sagittal jaw base relationship among different populations [45] including the Syrian [47].
5. **Articulare (Ar)**. The point of intersection of the external dorsal contour of the mandibular condyle and the temporal bone (or the junction of the averaged posterior surface of the rami and the base of the skull) [2, 48–50].
6. **Condylion (Co)**. The top of the condylar head of the mandible [50, 51].
7. **Lateral Cephalometric reference coordinate system**: a horizontal plane **HPL** (S to N line), and vertical plane **VPL** (line perpendicular to **HPL** through **S**) were used to build a reference coordinate system for liner measurements on lateral cephalograms [9, 52].
8. To describe the mandibular condyle position on the lateral cephalograms, the x, y coordinates of **Condylion** landmark [12, 55] were measured and digitized in relation to the cephalometric reference coordinate planes (**HPL**, **VPL**), beside the liner measurement: **S-Ar** [53].

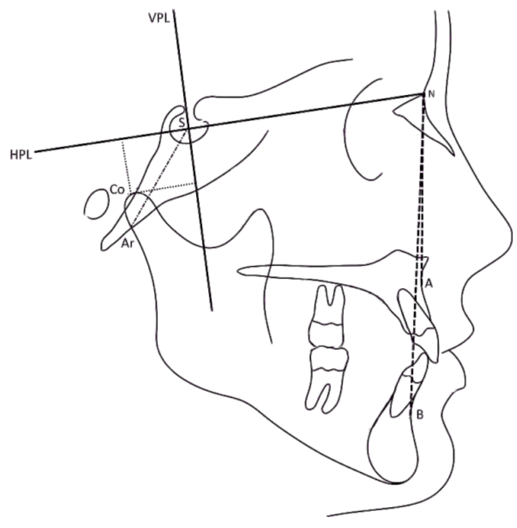

Figure 3. Landmarks, reference planes and measurements on lateral cephalograms

Error of method: to evaluate individual landmark intraoperator reproducibility, same researcher redigitized all cephalograms 1 month later using the same Audax-Ceph software. Random and systematic errors were calculated using the coefficient of reliability and a two-sample t-test where the level of significance was 0,95 for the random error values. None of the measurements between the first and the second digitizing was found to be statistically significantly different at the P < 0,1 for systematic errors.

Statistical method. Using Microsoft Excel of Microsoft office 2013, t-Test analysis of the x, y coordinates of left and right cephalometric landmarks on the postero-anterior cephalograms was performed to verify face transverse and vertical frontal facial symmetry. Furthermore, Pearson's Correlation Coefficient was calculated to investigate the relationship between the measurements describing the position of left and right mandibular condyles on the postero-anterior cephalograms, and the measurements describing the mandibular condyle position on the lateral cephalograms.

Results

Descriptive statistics for cephalometric measurements estimated of Jaws Rotation according to Björk (regardless of gender, male, female) are shown in Table 1 and Table 2.

To verify face transverse and vertical frontal symmetry, t-Test analysis ($\alpha = 0.05$) of the x, y coordinates of **(CondR)**, **(CondL)**, **CoL(R)**, **CoL(L)**, **(ArR)**, **(ArL)** was performed**.** No statistically significant differences was found between the left and right measurements on the postero-anterior cephalometric (Tab. 2).

Table 2. t-Test analysis ($\alpha = 0.05$) of the x, y coordinates of the left and right measurements on the postero-anterior cephalograms

	P
CondR-X	0.34
CondL-X	
CondR-Y	0.34
CondL-Y	
CoL(L)-X	0.35
CoL(R)-X	
CoL(R)-Y	0.32
CoL(L)-Y	
ArR-X	0.26
ArL-X	
ArR-Y	0.32
ArL-Y	

Pearson's Correlation test was performed to investigate the relationship between the measurements describing the position of left and right mandibular condyles on the postero-anterior cephalograms, and the measurements describing the mandibular condyle position on the lateral cephalograms. Results of this test are presented in Table 3.

Table 1. Descriptive statistics for postero-anterior and sagital cephalometric measurements

	Mean	Standard Error	Standard Deviation	Sample Variance	Range	Min.	Max.	Confid. Level: 95 %
ANB	2.31	0.37	1.43	2.03	3.53	0.47	4.00	0.79
SNA	78.77	1.15	4.47	19.97	17.97	71.55	89.52	2.47
SNB	76.47	0.99	3.85	14.81	15.60	71.00	86.60	2.13
CO-X	15.83	0.82	3.18	10.11	11.87	9.73	21.60	1.76
CO-Y	15.90	1.19	4.61	21.22	16.91	9.85	26.76	2.55
S-Ar	33.87	1.04	4.02	16.14	16.19	24.52	40.71	2.22
CondR-X	52.91	0.76	2.95	8.73	10.56	48.36	58.92	1.64
CondL-X	52.82	0.81	3.12	9.72	11.78	47.74	59.52	1.73
CondR-Y	38.51	1.38	5.36	28.76	17.07	29.23	46.30	2.97
CondL-Y	38.73	1.36	5.26	27.69	18.79	29.57	48.36	2.91
CoL(L)-X	60.56	1.25	4.84	23.46	19.31	54.32	73.63	2.68
CoL(R)-X	60.52	1.27	4.92	24.25	19.73	53.63	73.36	2.73
CoL(R)-Y	46.37	1.48	5.73	32.84	21.99	33.42	55.41	3.17
CoL(L)-Y	46.42	1.52	5.90	34.81	22.72	32.98	55.70	3.27
ArR-X	55.59	0.97	3.74	13.99	12.24	51.00	63.24	2.07
ArL-X	55.66	0.93	3.58	12.84	11.93	51.16	63.09	1.98
ArR-Y	53.54	1.44	5.59	31.23	19.31	42.83	62.14	3.09
ArL-Y	53.14	1.73	6.72	45.13	23.29	41.84	65.13	3.72

Table 3. Pearson's Correlation test between the measurements describing the mandibular condyle positions on the postero-anterior cephalograms and the measurements describing the mandibular condyle position on the lateral cephalograms

	CO-X	CO-Y	S-Ar
CondR-X	0.07▲	0.39▲	0.35▲
CondL-X	0.20▲	0.31▲	0.39▲
CondR-Y	0.30▲	0.33▲	0.81▲▲▲
CondL-Y	0.31▲	0.26▲	0.71▲▲▲
CoL(L)-X	-0.11▼	0.48▲	0.11▲
CoL(R)-X	-0.09▼	0.48▲	0.15▲
CoL(R)-Y	0.42▲	0.18▲	0.70▲▲
CoL(L)-Y	0.39▲	0.22▲	0.68▲▲
ArR-X	0.40▲	0.09▲	0.33▲
ArL-X	0.45▲	0.07▲	0.36▲
ArR-Y	0.09▲	0.14▲	0.41▲
ArL-Y	0.10▲	0.10▲	0.28▲

▲: Positive **weak** strength of correlation, ▲▲: Positive **Moderate** strength of correlation. ▲▲▲: Positive **Strong** strength of correlation, ▲: Negative **weak** strength of correlation.

Within all sample's subjects, Pearson's Correlation test showed positive (but vary in strength) correlation between cephalometric measurements determining the vertical position of left and right mandibular condyles on the postero-anterior cephalograms and the lateral cephalograms liner measurement (**S-Ar**), it should be noted that the x, y coordinates of the left and right **Articular** showed the weaker correlation with the lateral cephalograms liner measurement (**S-Ar**). Nevertheless, the lateral cephalograms liner measurement (**S-Ar**) showed weak correlation with cephalometric measurements determining transverse position of left and right mandibular condyles on the postero-anterior cephalograms.

The x, y coordinates of **Condylion** landmark on the lateral cephalograms showed weak correlation with cephalometric measurements determining booth vertical and transverse position of left and right mandibular condyles on the postero-anterior cephalograms.

The results of Pearson's Correlation test between the measurements describing the mandibular condyle positions on the postero-anterior cephalometric and the measurements describing the mandibular condyle position on the lateral cephalograms within all subjects of the sample visually shown in Chart 1.

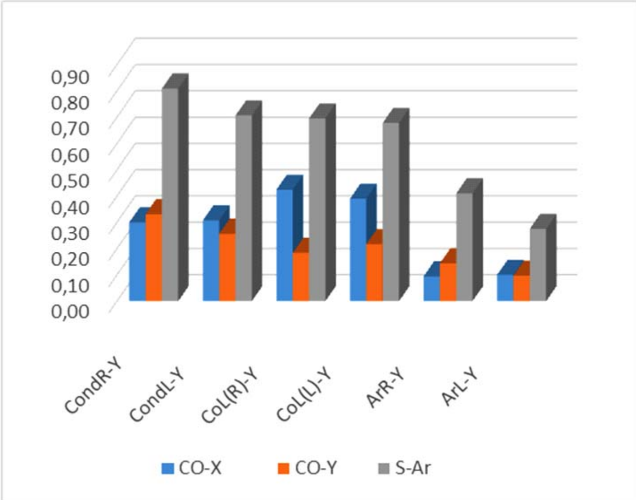

Chart 1. The results of Pearson's Correlation test between the measurements describing the mandibular condyle positions on the postero-anterior cephalometric and the measurements describing the mandibular condyle position on the lateral cephalograms

Discussion

A great body of literature concerning the mandibular condyle position according to sagittal skeletal relationship concentrated on its spatial location in the glinoid fossa, commonly in sagittal plane [4, 15, 18, 55–58], Several cephalometric researches inspected the condylar position in the sagittal plane corresponding to cranial base, orofacial complex [1, 2, 3], to the other TMJ's elements, and external auditory meatus [4, 5]. Whereas In the frontal plane, cephalometric researches inspected the most the influence of the condylar position in facial asymmetry patients [6,7]. In the current investigation, the relationship between the mandibular condyle position in the sagittal and frontal planes by means of both postero-anterior and lateral cephalograms amongst orthodontically non-treated skeletal class I adult females with no facial asymmetry, no history of temporomandibular joint disorders (nor any clinical signs of it) has been studied So, objects of present study were subjected to meticulously and high accuracy of clinical examination to exclude possible TMD'S patients. Moreover, since there is a significant difference in the craniofacial skeleton as a whole and in the transverse dimension of the TMJ specifically are known to exist between modern human males and females [54], the subject and goals of current study were focused on objects of females. Further investigation in this field must be attained for objects of males.

In the present paper we have demonstrated that amongst the liner lateral cephalometric measurements **S-Ar** hade the strongest statistically significant correlation with vertical position of left and right mandibular condyles (booth **Condylar** and **Condylion lateral** landmarks on the right and left sides have positive statistical significant correlation) on the postero-anterior cephalograms. This can be explained by the fact that **S-Ar** as intersection of the external dorsal contour of the mandibular condyle and the temporal bone, so once the temporal bone, and hence the glenoid fossa, is displaced downward and forward or backward and upward as a result of the cranial base rotation and consequently brings about changes in the mandibular position [26]. This was in agreement with Athanasiou who studied postero-anterior cephalograms of healthy.588 Austrian schoolchildren (157 girls and 431 boys, who were 6 to 15 years old) with various types of occlusions and did not receive orthodontic or orthopedic therapy. Athanasiou declared that there is no doubt that the growth in length and height played a paramount role on the transverse dentofacial structure [59]. However, **S-Ar** showed a weak relationship with booth vertical and transverse position of left and right postero-anterior cephalometric landmark **Ar**. This could be due to the way of construction of postero-anterior cephalometric landmark **Articular** which it's the intersection point of outline of maxillary tuberosity and the lateral outline of the condyle. The maxillary tuberosity doesn't belong to the cranial base (as the lateral cephalometric landmark **Articular)**, it's related to the growth progression of the maxilla as a whole, and to the process of the dentition of the upper molars particularly [60]. Anyway, the lateral cephalograms liner measurement (**S-Ar**) showed weak correlation with cephalometric measurements determining transverse position of left and right mandibular condyles on the postero-anterior cephalograms. This can be explained by the fact that some aspects of the TMJ appear to have developed in correlation with the craniofacial region, while others develop independently of it. The transverse dimension varies in accordance with size-related factors such as gender and correlates highly with other size related cranial measurements sagital-related dimensions, on the other hand, remain constant, as do some other cranial-base measurements [54]. For example, much of the vertical ramal growth occurs at the mandibular condyle with large impact on the sagittal growth of the mandible and flattening of the facial profile [61]. These differences in spatial constraints may in part explain the differences noted in weak correlation of the liner measurement (**S-Ar**) on the lateral cephalograms with the measurements determining transverse position of left and right mandibular condyles on the postero-anterior cephalograms. Furthermore, the undeniably fact that the facial growth has been reported to end first in width, then in length, and finally in height [62] can be an additional explanation of the weak correlation of the liner measurement (**S-Ar**) with the measurements determining mandibular condyles transverse position.

As mentioned previously, the results of our study revealed a weak correlation between the x, y coordinates of lateral cephalometric landmark **Condylion** and all measurements determining booth vertical and transverse position mandibular condyles on the postero-anterior cephalograms. This could be due of using **HPL** (**S** to **N** line) to build the lateral cephalometric reference coordinate system, which is morphologically less stable comparing with the **GWSO plane** we used to build the postero-anterior cephalometric reference coordinate system. No previous researches studied the relationship of lateral cephalometric landmark **Condylion** with the mandibular condyles position on the postero-anterior cephalograms can be compare with.

CONCLUSION

Amongst orthodontically non-treated skeletal class I adult females with no facial asymmetry, no history of TMDs, nor any clinical signs of it:

1. The liner lateral cephalometric measurements **S-Ar** hade the strongest statistically significant correlation with vertical position of left and right mandibular condyles on the postero-anterior cephalograms.
2. The liner lateral cephalometric measurements **S-Ar** have a positive statistical significant correlation with vertical position of left and right mandibular condyles on the postero-anterior cephalograms.
3. The left and right **Articular** on the postero-anterior cephalograms showed the weaker correlation with the position of mandibular condyles on the lateral cephalograms.
4. The lateral cephalometric landmark **Condylion** have weak correlation with the all measurements determining booth vertical and transverse position mandibular condyles on the postero-anterior cephalograms.

Clinical significance. Since the condyle position is one of the components of vertical and horizontal malocclusions, we tried in this research to describe the relation of condyle position to the cranial base in both frontal and sagital planes amongst skeletal class I adult females, so it can generally be considered an indicator in diagnosis of a certain type of malocclusion. However, to use the present data in a meaningful way, attention must be paid to the necessary prerequisites for taking proper postero-anterior cephalometric x-ray films particularly in complicated orthodontics cases of facial asymmetry and/or TMDs patients.

Limitation of Study. The limitations of present study must be acknowledged because of the large individual variation of the malocclusions and the morphological characteristics depicted in these various types of malocclusions. Moreover, a three-dimensional analysis using CBCT can probably access the position of mandibular condyles more accurately as compared to two-dimensional cephalometric analysis and can be a future possibility of research.

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