مجلة جامعة تشرين للبحوث والدراسات العلمية _ سلسلة العلوم الصحية المجلد (37) العدد (1) 2015
Tishreen University Journal for Research and Scientific Studies - Health Sciences Series Vol. (37) No. (1) 2015

Dimensions of Atlas and its Relation with Jaws Rotation (CBCT Scan Study).

Dr. Yazan Jahjah *
Dr. Hazem Hassan**

(Received 6 / 1 / 2015. Accepted 1 / 2 / 2015)

□ ABSTRACT □

First Cervical Vertebra (Atlas) belongs to the Atlantoaxial joint which connects the base of the skull to the spine. It plays a highly significant role in the growth and function of the craniofacial complex. Atlas has function-anatomical interrelationship with the TMJ. That means the Axis is involved in the morphogenetic and function of the jaws.

Aim To investigate the relationship of Atlas's dimensions with jaws rotation in adult orthodontically non-treated subjects using CBCT scan.

Materials and methods: The study sample included 30 Caucasian patients (12 males, 18 females) from 19 to 25 years of age, (mean age of 21.1 years) with no history of prior orthodontics, and who had to have a CBCT scan for non-neurological disorders purpose (but not especially for this study). Cephalometric jaws rotation study was performed according to Björk and Skieller on CBCT-derived 2-dimensional lateral cephalograms. *Pearson's Correlation Coefficient* was calculated.

Results: This study reveals variant correlations between CBCT measurements of Atlas's dimensions and jaws rotation according to the gender, although CBCT measurements of Atlas's dimensions showed no statistical significant differences between the two genders.

Conclusion There is a relationship between the morphology of the Atlas and Jaws rotation in adult orthodontically non-treated subjects.

KeyWords: first cervical vertebra; CBCT scan; dimensions of Atlas; jaws rotation.

***Asst. Professor at Orthodontics and Dentofacial Orthopedic Department, Dental School at Tishreen University. Syria.**
**** Professor at Orthodontics Department, Dental School at Tishreen University. Syria**

مجلة جامعة تشرين للبحوث والدراسات العلمية _ سلسلة العلوم الصحية المجلد (37) العدد (1) 2015
Tishreen University Journal for Research and Scientific Studies - Health Sciences Series Vol. (37) No. (1) 2015

أبعاد الفهقة وعلاقتها بدورانات الفكين (دراسة بواسطة الطبقي المحوري المخروطي).

الدكتور يزن ججحاح*
الدكتور حازم حسن**

(تاريخ الإيداع 6 / 1 / 2015. قُبِل للنشر في 1 / 2 /2015)

□ ملخّص □

تنتمي الفقرة الرقبية الأولى (الفهقة) إلى الوصل القحفي الرقبي الذي يصل قاعدة الجمجمة مع العمود الفقري. ويلعب دوراً بالغ الأهمية في نمو ووظيفة المركب القحفي الوجهي، تمتلك الفهقة علاقة وظيفية – تشريحية متبادلة مع المفصل الفكي الصدغي، مما يعني أن الفهقة مرتبطة مع الفكين مورفولوجياً، وراثيا ووظيفياً.

هدف البحث: دراسة علاقة أبعاد الفهقة مع دوران الفكين لدى أفراد بالغين غير معالجين تقويمياً باستخدام التصوير الطبقي المخروطي

مواد وطرق البحث: أفراد العينة 30 بالغ من العرق قوقازي (12 ذكور،18 أنثى) بعمر ما بين 19 إلى 25 (متوسط العمر 21.1 سنة) ممن لم يخضعوا لمعالجة تقويمية سابقة وكانوا سلفاً (وليس لأجل هذه الدراسة) بصدد إجراء تصوير طبقي محوري مخروطي لأسباب لا تتعلق بمشاكل تقويمية أو بأمراض الجهاز العصبي. تمت دراسة دوران الفكين سيفالومترياً وفق Björk و Skieller وذلك على الصور الثنائية البعد التي تم الحصول عليها من صور الطبقي المحوري المخروطي؛ إحصائياً تم إجراء تحليل معامل ارتباط بيرسون (Pearson's Correlation Coefficient).

النتائج: بينت هذه الدراسة ارتباطاً متنوعاً ما بين قياسات الفهقة المجراة على صور الطبقي المحوري المخروطي وبين دوران الفكين وفق الجنس، على الرغم من عدم وجود فروقات ذات دلالة إحصائية في قياسات الفهقة المجراة على صور الطبقي المحوري المخروطي بين الجنسين.

الخلاصة: هناك علاقة ما بين أبعاد الفهقة وبين دوران الفكين لدى أفراد بالغين غير معالجين تقويمياً.

الكلمات المفتاحية: تصوير طبقي محوري المخروطي للفقرة الرقبية الأولى، قياسات الفهقة، دوران الفكين.

* مدرس – قسم تقويم الأسنان والفكين –كلية طب الأسنان – جامعة تشرين– اللاذقية– سورية.
** أستاذ مساعد –قسم تقويم الأسنان والفكين –كلية طب الأسنان – جامعة تشرين– اللاذقية– سورية.

Introduction:

Atlas or what can be anatomically called also: Atlas (CI), C1 Vertebra, First Cervical Vertebra, Cervical Vertebra 1, the atlas is different from all other cervical vertebrae in its lack of a body, It's a bone, which has a shape of ring with prominent lateral masses, these lateral masses are the thickest part of the bone. The major features of the lateral masses are the superior and inferior articular facets. Projecting laterally from each lateral mass is the transverse process. Perforating this projection of bone is the transverse foramen, a small hole that passes through the process. The two lateral masses are connected anteriorly and posteriorly by slender arches of bone, the anterior arch being shorter and thinner than the thicker, longer posterior arch.

Axis (Cervical vertebra 2): This vertebra differs from other cervical vertebrae in its possession of a dens or odontoid process. This tooth-like process projects superiorly from the vertebral body forming a pivot around which the ring-like atlas rotates. It is the bulkiest of the cervical vertebrae. Unlike other cervical vertebrae, its superior and inferior articular facets do not sit in line with one another, the superior facet sitting anterior to the inferior facet

Atlas along with the Axis – forms the joint connecting the skull and spine: Atlantoaxial joint (fig1).Atlantoaxial joint its self is the articulation between the first two cervical vertebrae, (Atlas & Axis), and their associated serial homologue, the occipital bone at the base of the skull, form the most mobile of the vertebral joints. These specialized vertebral elements allow for the wide range of motion of the cranium. In conjunction with their specializations and range of motion, a varied array of important ligaments support these boney elements [**خطأ! لم يتم العثور على مصدر المرجع.**].

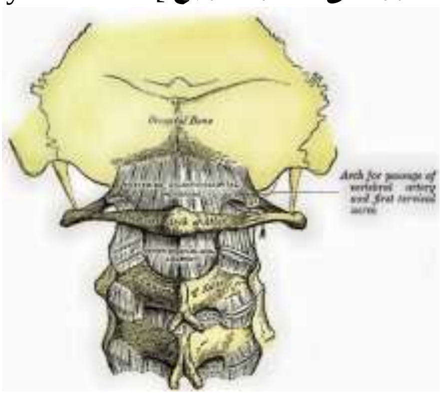

Figure 1: an anatomical dorsal overview of the Atlantoaxial joint [خطأ! لم يتم العثور على مصدر المرجع.**].**

The cervical spine is surrounded by strong ligaments that hold the individual spinal segments together and is surrounded by a muscular apparatus that supports and moves in coordination and harmony between the column and the head through atlanto occipital joint which allows moderate lateral flexion movements, 10 degrees of flexion and extension 25; a few degrees in the same direction are also allowed by the joint reports between C1 and C2.[2]. Among the basal structures of the neurocranium, the occipital bone around the foramen magnum is the first to ossify (between the third and fourth year of life). This appears to be indispensably necessary, as the head is supported by the trunk precisely in this area [3]. When the child learns to walk in an upright position, the structures around the foramen magnum must be solid enough to resist the force of gravity, otherwise the trunk would intrude into the brain [4]. The shape of the cranial base may be considered on an average, to remain stable with age [5], and well function as a logical consequence, the craniofacial structures at the junction between the skull and the trunk essentially deserve to be considered as the center from which the radiating development of the craniofacial skeleton takes place [3].

The Atlas, which holds the weight of the head (about 10-15 lb), is the junction element between cranial base and vertebral column. The dens of the ring that rotates atlas (atlas sub-area) is the point of origin of muscle function that determines the physiological occlusion while the Atlantoaxial joint act as connectors suspended the jaw to the skull and act as secondary areas of balance during mastication [6].

One might think that when the mandible opens and closes, its movement is centered around the condyle in the TMJ itself. However, this is not the case. According to the Quadrant Theorem of Guzay [7, 8, 9, 6] the axis of rotation of the mandible lies exactly at the odontoid of C2. (The odontoid is the upward, toothlike protuberance from the second vertebra, around which the first vertebra rotates.) When the mandible moves downwards, this generates a pulling force, loosening the muscles around C2. Likewise, when moving up (i.e., when closing the mouth), it generates a pressure, which tightens the muscles around C2. This means that in an occlusion with decreased vertical dimension will aggravate muscle tension around C2 when the mouth is closed. Therefore, it is clear that distortion in TMJ will affect the position of the Axis too, so Axis acts as the pivot on mandibular movement (fig2) [6].

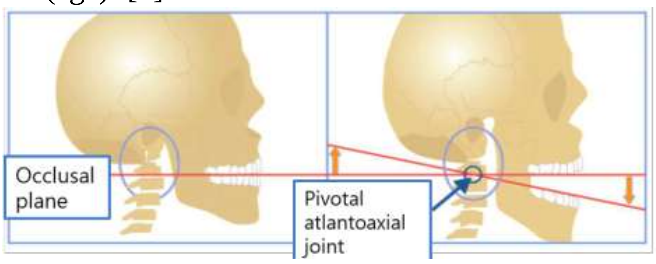

Figure 2 how Axis acts as a pivot on mandibular movement [6].

Müller [10, 11] claimed this should be considered in studying facial growth, because the spatial development of a treetop should not be assessed from a twig in the periphery but, rather, from the junction between trunk and top. Accordingly, craniofacial growth is evaluated more objectively from the occipital structures at the junction between skull and trunk. The mandible exists in the center of a chain of muscles that act in close harmony to control the position of the head in space [12]. Huggare (in a cephalometric study) regarded the first cervical vertebra as a predictor for mandibular growth; he found that among non-treated cases there was a significant correlation between horizontal growth of the mandible and the initial height of the atlas dorsal arch [13]. He also found (in a cephalometric study) an association between morphology of the first cervical vertebra, and head craniofacial structures [14]. Liu concluded (in a cephalometric study) that when the atlas size ratio increased, a reduction of the amount of mandibular horizontal growth was showed, and the mandibular rotated backward; on the contrary, when the atlas size ratio decreased, the amount of mandibular horizontal growth increased and the mandibular rotated forward [15]. Nisayif, studying the relationship between the morphology of Atlas and the direction of mandibular rotation in Iraqi adults, concluded that the morphology of atlas could be regarded as a predictor for mandibular rotation [16]. Björk and Skieller were first who describe upper and lower jaws rotations during human growth and development. They described the rotation in terms of either a forward or a backward direction. Forward rotation occurs when there is more vertical facial growth posteriorly than anteriorly. For backward rotation this pattern is reversed, relatively greater vertical growth occurring anteriorly compared to posteriorly. This vertical rotation of the maxillary complex is generally less than that seen in the mandible due to the contribution of middle cranial fossa growth [17-22].

Study Objectives

The aim of this study is to investigate the relationship of Atlas's dimensions with jaws rotation in adult orthodontically non-treated subjects using CBCT scan.

MATERIALS AND METHODS

-*Subjects.*

Sample's subjects were selected from patients who, any way, had to have a CBCT scan for non-neurological disorders purpose, but not especially for this study.

Criteria for selecting the subjects:

1)No history of neurological disorders and/or neurological traumas.
2)No clinical or CBCT symptoms of neurological disorders and/or neurological traumas
2) No history of trauma to the dento-facial structures.
3) No history of abnormal habits, with patients showed normal nasal breathing
4)Subjects must have fully erupted permanent dentition up to second molar teeth.
5)No supernumerary teeth / missing teeth / impacted teeth.
6)Exclusion criteria also were subjects with congenital anomalies/ evident signs of neurological impairment and/or syndromes and/or dentoskeletal asymmetries and/or craniofacial malformation.

Sample estimation

To determine the minimum sample size to be statistically significant, a pilot study was applied on 22 subject (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), (σ): highest Standard Deviation value within all the variables (σ = 10.6)

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

Thus:

$$n = \frac{(2.58)^2 (10.60)^2}{5^2} \approx 29.91$$

According to this 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 29.91 patients as minimum.

The size of this study's sample was 30 Caucasian patients (12 males, 18 females) from 19 to 25 years of age, (mean age of 21.1 years: Males average age was 23.1; Females average age was 20.2) with no history of prior orthodontics treatment

- *CBCT study:*

CBCT scans were obtained in centric occlusion (maximum dental intercuspation); data were obtained using a 3D cone-beam volume scanner (SCANORA® 3D FOVs.). Used settings were as following: Standard scan mode with an imaging volume of 40 cmx13 cm, Scan speed of 9 s, Slice thickness 0.3 mm, 120 kV, 47mA. Orientation was established as was recommended by Baratieri [23] and Alves [24] by three reference planes: 1- the axial plane, passing through the right and left Orbitale points as well as the right and left Porion accordingly; 2- the coronal plane, passing through the left and right Porion perpendicular to the chosen axial plane; 3- the sagittal plane, passing through the Nasion point, perpendicular to the chosen axial and coronal planes.

CBCT Atlas measurements:

On the 3D CBCT grams, an anterior-posterior and transversal CBCT Atlas measurements were taken from the superior aspect on the axial plane. Tow CBCT Atlas measurements were taken on the sagital plane. All the CBCT Atlas measurements are liner and they were performed by one and the same author (in mm) digitally using the CBCT software, CBCT digital measurements accurate to the nearest 0.01 mm.

We did not use borders of Atlas's foramens for the reason that Awadalla (2009) found in his study (on vertebral artery groove of the Atlas on 76 dry specimens) that 57.96% of the examined specimens presented with a bridge (partial and complete) formation which projects over the vertebral artery groove and could lead to its anatomical destandardization [25].

−*CBCT Atlas measurements taken from the superior aspect on the axial plane:*

1-(**HIAPC1**): Horizontal inner anteroposterior diameter of C1 [26].

2-(**Superior surface**) anteroposterior diameter of superior surface of the Atlas's anterior arch [26].

3-(**HOTDC1**): Horizontal outer transverse diameter of C1 [26].

4-(**Inner margin**): We defined it as the minimum transverse diameter of the vertebral canal was measured perpendicularly to the midsagittal plane passing through the canal's nearest points.

5-(**Outer margin**) We defined it as the maximum transverse diameter of the anterior part of the Atlas was measured perpendicularly to the midsagittal plane passing through uttermost lateral points of the posterior edges of the Atlas.

Atlas measurements taken from the superior aspect on the axial plane are shown in fig 3.

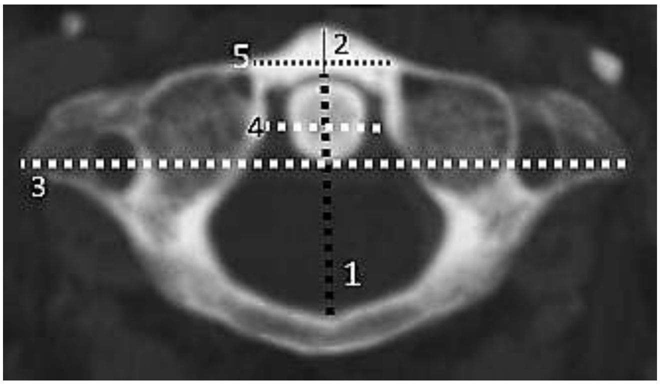

Figure 3: CBCT Atlas measurements taken from the superior aspect on the axial plane.

−*CBCT Atlas measurements taken on the sagital plane:*

1-(LOAPC1) The maximum Lateral outer anteroposterior diameter of C1 [27, 28].

2-Height of the atlas dorsal arch (dorsal arch): we defined it as the maximum distance between the upper and lower border of the dorsal arch in the sagital plane. We did not follow Huggare [13, 14], and Nisayif [16] recommendation in measuring the Height of the atlas dorsal arch as the maximum vertical extent of the atlas dorsal arch perpendicular to the anteroposterior length of the atlas, because the shaft of the Height of the atlas dorsal arch anatomically not always perpendicular to the anteroposterior length of the atlas.

CBCT Atlas measurements taken on the sagital plane are shown in fig 4.

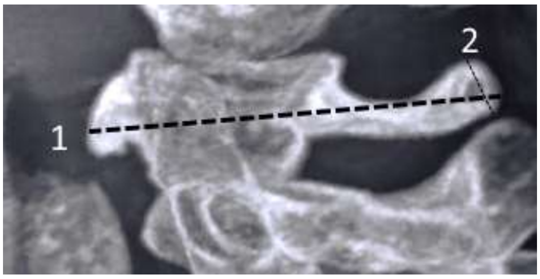

Figure 4: CBCT Atlas measurements taken on the sagital plane.

-*lateral cephalometric analysis (fig5):*

Moshiri [29] found that CBCT-derived 2-dimensional lateral cephalograms proved to be more accurate than lateral cephalograms for most linear measurements calculated in the sagittal plane. Kumar [30] concluded that measurements from in vivo CBCT synthesized cephalograms are similar to those based on conventional radiographic images. Ludlow [31] found also that CBCT volume images provide generally more precise identification of traditional cephalometric landmarks. In this study, lateral cephalometric analysis was performed by Kumar [30] method using the CBCT scans, which were obtained in centric occlusion.

All digital cephalometric measurements were performed by one and the same author (angles measurements in degrees) digitally using the CBCT software. Liner CBCT digital measurements accurate to the nearest 0.01 mm. whereas angular measurements were accurate to the nearest 0.01 degrees.

Cephalometric evaluating Jaws Rotation was performed according to Björk and Skieller [18, 19, 21, 22, 32, 33].

Planes and lines that have been used in this investigation according to Björk and Skieller [18, 19, 21, 22, 32, 33], were formed by the following facial components:

-Nasion-Sella line (NSL): the plane of the anterior cranial base, it is a line drawn from nasion (N) to Sella (S).which it is the center of sella turcica

-Nasal Line (NL): it is the Palatal plane, a line drawn from the apex of the anterior nasal spine (ANS) to the apex of the posterior nasal spine (PNS).

-S-Ar: A line drawn from the center of sella turcica (S) to articular (Ar) (Ar is the point. of intersection of the dorsal contour of the articular processes of the mandibular condyle and the temporal bone).

-Ar-Go: A line drawn from articular (Ar) to Gonion (Go) (Go is the point of intersection between lines tangent, to the base and ramus of the mandible.

-ML1: It is the Mandibular plane 1, the tangent, to the base of the mandible.

-ML2: It is the Mandibular plane 2, formed by a line joining Gonion (Go) and Menton (Me) (Me is the lowest point of the outer border of the Mandibular symphysis).

Cephalometrics liner measurements that have been used in this investigation according to Björk and Skieller [18, 19, 21, 22, 32, 33]:

N-Me: Anterior facial height: A linear distance from Nasion to Menton.

S–Go: Posterior facial height: A linear distance from Sella to Gonion constructed.

Index I: This index is an expression of the proportion between the posterior and the anterior facial height. It represented Mandibular inclination [33]. Index I calculated as following :

$$Index.I = \frac{S - Go}{N - Me} = 63.6 \pm 6.4$$

Cephalometrics angular measurements that have been used in this investigation according to Björk and Skieller [18, 19, 21, 22, 32, 33]:

Saddle angle (S): an angle between anterior and posterior cranial base

Articular angle (Ar): an angle between posterior cranial base and ramus height. Björk called (Articular angle): the angle at the temporomandibular joint [32].

Gonial angle (Go): an angle between lines tangent, to the base and ramus of the mandible.

Sum angles according to Björk (Björk ∑): sum of angles Saddle angle (S), Articular angle (Ar), and Gonial angle (Go).

Upper Gonial angle (Go1): an angle between ramus height and Gonion constructed- Nasion line (AR-GO-ME)

Lower Gonial angle (Go2): an angle between Gonion constructed-Nasion line and is the Mandibular plane 2 (ML2).

NL-NSL: an angle between the anterior cranial base and Nasal Line (in some literatures Nasal Line it is Palatal plane).

ML-NSL: an angle between the anterior cranial base and ML1.

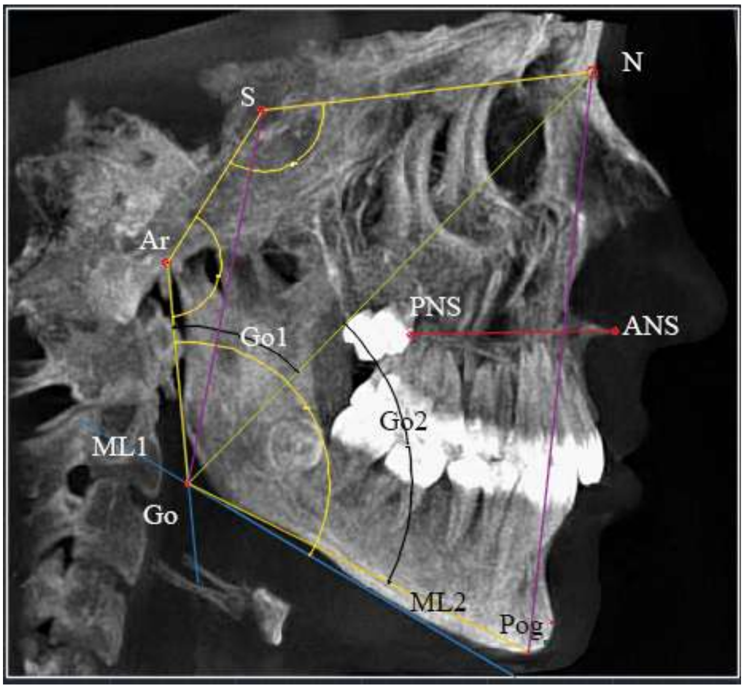

Figure 5: Cephalometrics points and measurements that have been used in this investigation according to Björk and Skieller [18, 19, 21, 22, 32, 33].

−*Error of method:*

The same examiner repeated all CBCT measurements twice with two months interval. Initial and repeated measurements were compared by using a paired t-test at α= 0.05 to check any systematic error. The t-test did not show any statistical significance of the differences.

−*Statistical method:*

Using Microsoft Excel of Microsoft office 2013, Pearson's Correlation Coefficient was calculated to investigate the strength of the linear association of all of the **CBCT measurements** of **Atlas's dimensions** with all **cephalometrics measurements** that have been used in this investigation with purpose of determining jaws rotation (according to Björk and Skieller)

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.

Table 1: Descriptive statistics for cephalometric measurements estimated Jaws Rotation according to Björk (regardless of gender, male, female) part 1.

Gender	Descriptive statistics	*S*	*Ar*	*Go*	Björk ∑	*Go1*	*Go2*
♂&♀	Mean	125.78	144.82	122.68	393.28	49.75	72.94
	Standard Error	1.08	2.10	1.92	1.88	1.28	1.50
	Standard Deviation	4.20	8.15	7.45	7.29	4.94	5.81
	Sample Variance	17.64	66.43	55.51	53.15	24.42	33.71
	Range	18.22	30.70	28.78	27.07	15.48	20.03

	Minimum	112.72	132.80	109.29	382.45	43.12	63.78
	Maximum	130.95	163.50	138.07	409.52	58.60	83.82
	Count	30	30	30	30	30	30
♂	Mean	126.21	141.67	121.31	389.18	50.80	70.51
	Standard Error	0.83	2.31	1.73	1.67	1.77	0.91
	Standard Deviation	2.05	5.66	4.24	4.09	4.35	2.23
	Sample Variance	4.18	32.04	17.95	16.72	18.90	4.97
	Range	5.63	15.59	10.95	12.31	12.54	6.62
	Minimum	124.57	132.80	116.86	382.45	46.06	67.93
	Maximum	130.20	148.39	127.80	394.76	58.60	74.55
	Count	12	12	12	12	12	12
♀	Mean	125.49	146.92	123.60	396.01	49.04	74.55
	Standard Error	1.76	3.05	3.05	2.61	1.81	2.32
	Standard Deviation	5.29	9.16	9.14	7.84	5.43	6.97
	Sample Variance	28.01	83.82	83.57	61.54	29.53	48.53
	Range	18.22	27.23	28.78	25.40	14.30	20.03
	Minimum	112.72	136.27	109.29	384.12	43.12	63.78
	Maximum	130.95	163.50	138.07	409.52	57.42	83.82
	Count	18	18	18	18	18	18

Table 2: Descriptive statistics for cephalometric measurements estimated Jaws Rotation according to Björk (regardless of gender, male, female) part 2.

Gender	Descriptive statistics	*S-Go*	*N-Me*	Index I	*NL-NSL*	*ML-NSL*
♂&♀	Mean	71.84	111.39	66.50	7.69	33.28
	Standard Error	1.94	1.64	1.50	0.83	1.88
	Standard Deviation	7.51	6.33	5.82	3.21	7.29
	Sample Variance	56.36	40.10	33.92	10.32	53.15
	Range	23.50	21.84	22.06	10.92	27.07
	Minimum	61.40	102.06	55.39	1.70	22.45
	Maximum	84.90	123.90	77.45	12.62	49.52
	Count	30	30	30	30	30
♂	Mean	77.16	114.90	69.92	6.12	29.18
	Standard Error	3.24	3.08	1.74	1.74	1.67
	Standard Deviation	7.93	7.55	4.27	4.27	4.09
	Sample Variance	62.83	56.94	18.21	18.21	16.72
	Range	15.20	21.84	11.34	10.92	12.31
	Minimum	69.70	102.06	66.11	1.70	22.45
	Maximum	84.90	123.90	77.45	12.62	34.76
	Count	12	12	12	12	12
♀	Mean	68.30	109.06	64.21	8.74	36.01
	Standard Error	1.63	1.46	1.92	0.63	2.61
	Standard Deviation	4.90	4.39	5.77	1.89	7.84
	Sample Variance	24.03	19.23	33.32	3.59	61.54
	Range	13.40	13.50	18.91	5.25	25.40

	Minimum	61.40	102.70	55.39	6.15	24.12
	Maximum	74.80	116.20	74.30	11.40	49.52
	Count	18	18	18	18	18

Descriptive statistics for CBCT of Atlas's dimensions (regardless of gender, male, female) are shown in Table 3 .

Table 3: Descriptive statistics for CBCT of Atlas's dimensions (regardless of gender, male, female).

Gender	Descriptive statistics	HIAP C1	superior surface	HOTD C1	inner margin	outer margin	LOAP C1	Height of the atlas dorsal arch
♂&♀	Standard Error	0.93	0.32	2.74	1.34	1.85	0.77	0.66
	Standard Deviation	3.60	1.24	10.60	5.18	7.17	2.98	2.57
	Sample Variance	12.93	1.54	112.26	26.83	51.36	8.91	6.59
	Range	13.30	4.60	42.50	18.40	23.39	9.80	8.46
	Minimum	25.20	2.30	50.00	13.40	17.00	34.80	5.50
	Maximum	38.50	6.90	92.50	31.80	40.39	44.60	13.96
	Count	30	30	30	30	30	30	30
♂	Standard Error	1.10	0.36	3.48	0.65	4.15	1.28	1.47
	Standard Deviation	2.70	0.87	8.52	1.59	10.16	3.14	3.59
	Sample Variance	7.31	0.76	72.61	2.51	103.30	9.84	12.91
	Range	7.05	2.49	23.17	4.00	23.39	8.12	8.46
	Minimum	26.10	3.40	50.00	15.50	17.00	34.80	5.50
	Maximum	33.15	5.89	73.17	19.50	40.39	42.92	13.96
	Count	12	12	12	12	12	12	12
♀	Standard Error	1.30	0.50	3.52	2.14	1.66	0.98	0.60
	Standard Deviation	3.90	1.49	10.56	6.41	4.98	2.95	1.80
	Sample Variance	15.23	2.22	111.54	41.07	24.85	8.71	3.25
	Range	13.30	4.60	40.50	18.40	16.00	9.40	5.90
	Minimum	25.20	2.30	52.00	13.40	20.10	35.20	5.60
	Maximum	38.50	6.90	92.50	31.80	36.10	44.60	11.50
	Count	18	18	18	18	18	18	18

t-Test analysis of CBCT measurements of Atlas's dimensions (shown in Table 4) reveal no statistical significant differences between the two genders ($\alpha = 0.05$).

Table 4 : t-Test analysis of CBCT measurements of Atlas's dimensions between the two genders (α= 0.05).

	P
HIAPC1	0.20
superior surface	0.90
HOTDC1	0.09
inner margin	0.27
outer margin	0.83
LOAPC1	0.45
Height of the atlas dorsal arch	0.68

Pearson's Correlation test was performed to determine the relationship between the **CBCT measurements** of **Atlas's dimensions** with all **cephalometrics measurements** that have been used in this investigation with purpose of determining jaws rotation according to Björk and Skieller (regardless of gender). Results of this test are presented in Table 5.

Table 5: Pearson's Correlation test between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within all subjects of the sample (regardless of gender).

	HIAPC1.	superior surface	HOTDC1	inner margin	outer margin	LOAPC1	Height of the atlas dorsal arch
S	-0.13▼	0.58▲▲	-0.21▼	-0.71▼▼	-0.42▼	-0.10▼	-0.15▼
Ar	-0.07▼	-0.74▼▼	0.14▲	0.67▲▲	0.13▲	0.04▲	-0.11▼
Go	0.63▲▲	0.38▲	0.05▲	-0.06▼	-0.26▼	0.12▲	-0.10▼
Björk ∑	0.49▲	-0.11▼	0.08▲	0.27▲	-0.37▼	0.11▲	-0.31▼
Go1	0.30▲	0.71▲▲	-0.04▼	-0.51▼▼	-0.27▼	0.04▲	0.13▲
Go2	0.56▲▲	-0.12▼	0.10▲	0.35▲	-0.11▼	0.12▲	-0.24▼
S-Go	-0.18▼	-0.14▼	-0.10▼	0.06▲	0.53▲▲	0.09▲	0.09▲
N-Me	0.00	-0.21▼	-0.18▼	0.14▲	0.51▲▲	0.07▲	0.00
Index I	-0.48▼	-0.07▼	-0.03▼	-0.15▼	0.49▲	-0.06▼	0.40▲
NL-NSL	0.13▲	-0.18▼	-0.21▼	-0.01▼	-0.65▼▼	-0.05▼	-0.19▼
ML-NSL	0.49▲	-0.11▼	0.08▲	0.27▲	-0.37▼	0.11▲	-0.31▼

Where:

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

▼: Negative **weak** strength of correlation, ▼▼: Negative **Moderate** strength of correlation, ▼▼▼: Negative **Strong** strength of correlation.

Within all sample's subjects, Pearson's Correlation test showed weak strength (with different direction) of correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller). Exclusion was a moderate, positive correlation showed by all of: HIAPC1 (with Go, and Go2), Superior Surface (with S), Inner Margin (with Ar) Outer Margin (with S-Go, and N-Ml). While a moderate, negative correlation showed all of Superior Surface (with Ar), Inner Margin (with S and Go1), and Outer Margin (with NL-NSL).

The results of Pearson's Correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within all subjects of the sample (both genders) visually shown in Chart 1

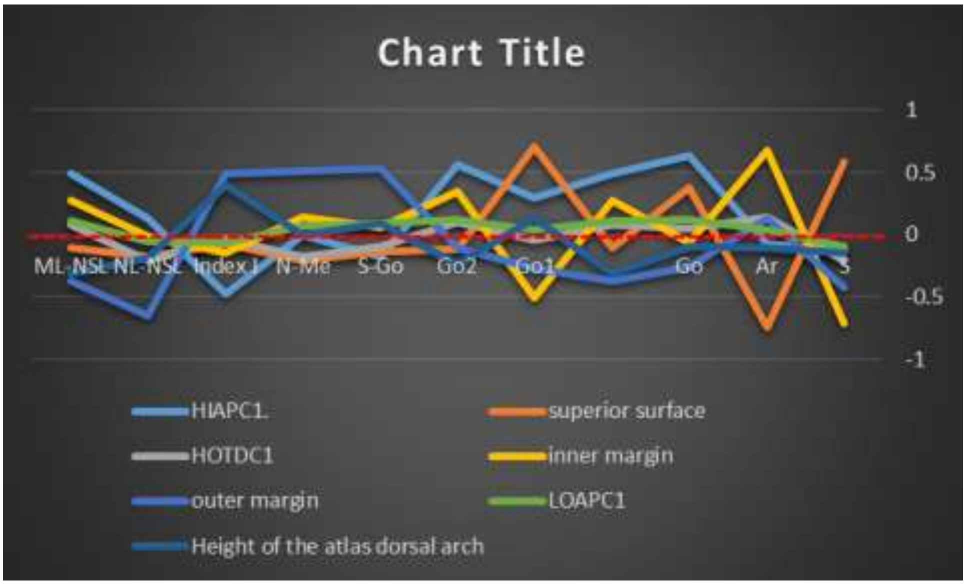

Chart 1: Results of Pearson's Correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within subjects of the sample (both genders).

Subjects of the sample (both genders) showed that (S) attending to have more negative direction and vary strength of correlation with CBCT measurements, other cephalometric parameters have vary correlation (in strength and direction) with Atlas's CBCT measurements.

Results of Pearson's Correlation test of the relationship between the CBCT **measurements** of **Atlas's dimensions** with all **cephalometrics measurements** that have been used in this investigation with purpose of determining jaws rotation according to Björk and Skieller within male subjects of the sample are presented in Table 6.

Table 6 : Pearson's Correlation test between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within male subjects of the sample.

	HIAPC1.	superior surface	HOTDC1	inner margin	outer margin	LOAPC1	Height of the atlas dorsal arch
S	0.70 ▲▲	0.90 ▲▲▲	0.49 ▲	0.18 ▲	-0.29 ▼	0.35 ▲	-0.10 ▼
Ar	-0.83 ▼▼▼	-0.63 ▼▼	-0.94 ▼▼▼	-0.45 ▼	-0.04 ▼	-0.70 ▼▼	-0.50 ▼▼
Go	0.65 ▲▲	0.30 ▲	0.67 ▲▲	-0.27 ▼	-0.66 ▼▼	0.20 ▲	0.50 ▲▲
Björk ∑	-0.13 ▼	-0.11 ▼	-0.36 ▼	-0.82 ▼▼▼	-0.87 ▼▼▼	-0.59 ▼▼	-0.22 ▼
Go1	0.86 ▲▲▲	0.57 ▲▲	0.88 ▲▲▲	0.14 ▲	-0.32 ▼	0.56 ▲▲	0.51 ▲▲

Go2	-0.45 ▼	-0.54 ▼▼	-0.44 ▼	-0.78 ▼▼	-0.63 ▼▼	-0.71 ▼▼	-0.04 ▼
S-Go	-0.16 ▼	-0.24 ▼	-0.27 ▼	0.32 ▲	0.53 ▲▲	0.38 ▲	-0.12 ▼
N-Me	-0.63 ▼▼	-0.57 ▼▼	-0.45 ▼	0.20 ▲	0.57 ▲▲	-0.11 ▼	-0.14 ▼
Index I	0.00 ▼	-0.15 ▼	0.33 ▲	0.72 ▲▲	0.86 ▲▲▲	0.50 ▲▲	0.35 ▲
NL-NSL	-0.05 ▼	-0.45 ▼	-0.60 ▼▼	-0.93 ▼▼▼	-0.73 ▼▼	-0.29 ▼	-0.10 ▼
ML-NSL	-0.13 ▼	-0.11 ▼	-0.36 ▼	-0.82 ▼▼▼	-0.87 ▼▼▼	-0.59 ▼▼	-0.22 ▼

Where:

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

▼: Negative **weak** strength of correlation, ▼▼: Negative **Moderate** strength of correlation, ▼▼▼: Negative **Strong** strength of correlation.

Cephalometric measurements determining jaws rotation in male subjects showed more strong correlation (but vary in direction) with CBCT measurements of Atlas's dimensions.

(S) have positive correlation with all of CBCT measurements of Atlas's dimensions (strong only with superior surface, and moderate only with HIAPC1, other positive correlation were weak) excluding Outer Margin and Height of the atlas dorsal arch (were weak negative correlation).

(Go1) also have positive correlation with all of CBCT measurements of Atlas's dimensions (strong with HIAPC1, and HOTDC1, moderate correlation with LOAPC1 and Height of the atlas dorsal arch,) excluding Outer Margin which had weak negative correlation with (Go1).

(Index I) (Ar), Björk ∑, (Go2), NL-NSL and ML-NSL have negative correlation (but vary in strength) with all of CBCT measurements of Atlas's dimensions

Both (S-Go) and (N-Me) had negative correlation with HIAPC1, superior surface, and HOTDC1 (but vary in strength) and weak negative correlation with Height of the atlas dorsal arch, (N-Me) had also negative correlation (but weak) with LOAPC1 and Height of the atlas dorsal arch.

(Go) have positive correlation with all of CBCT measurements of Atlas's dimensions (but vary in strength) excluding inner margin (weak negative correlation) and Outer Margin (moderate negative correlation).

The results of Pearson's Correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within male subjects of the sample visually shown in Chart 2

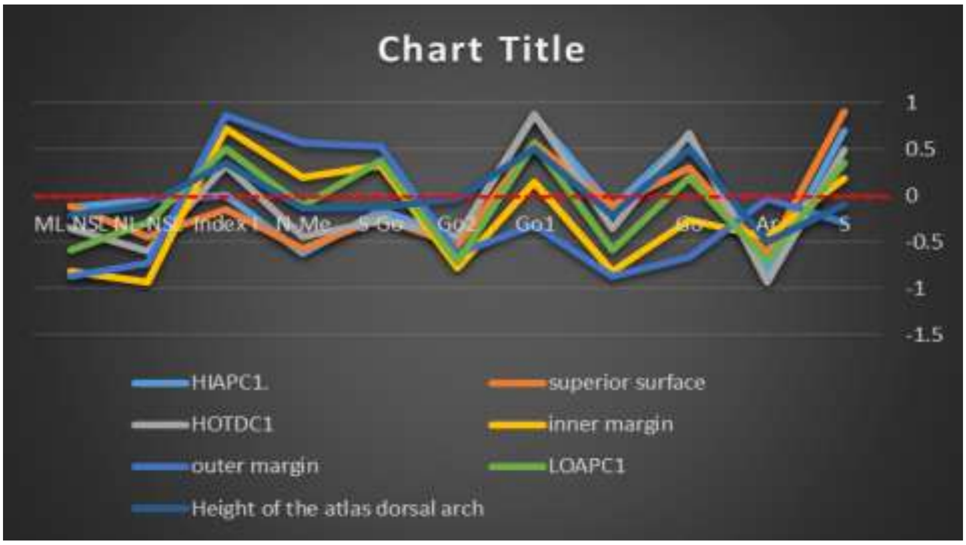

Chart 2: Results of Pearson's Correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within male subjects of the sample.

Male subjects of the sample showed that (NL-NSL), (ML-NSL), (Go2), and (Ar) have negative direction with vary strength of correlation with all of CBCT measurements of Atlas's dimensions, while (Index I), (N-Me), (S-Go), (Go1) and (Go) have vary correlation (in strength and direction) with Atlas's CBCT measurements. It is also clear that (Index I), (Go1), (Go) and (S) attending to have more positive direction and vary strength of correlation with CBCT measurements.

Results of Pearson's Correlation test of the relationship between the **CBCT measurements** of **Atlas's dimensions** with all **cephalometrics measurements** that have been used in this investigation with purpose of determining jaws rotation according to Björk and Skieller within female subjects of the sample are presented in Table 7.

Table 7 : Pearson's Correlation test between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within female subjects of the sample.

	HIAPC1	superior surface	HOTDC1	inner margin	outer margin	LOAPC1	Height of the atlas dorsal arch
S	-0.25▼	0.55▲▲	-0.33▼	-0.77▼▼	-0.70▼▼	-0.20▼	-0.27▼
Ar	-0.05▼	-0.83▼▼▼	0.28▲	0.76▲▲	0.36▲	0.24▲	0.23▲
Go	0.63▲▲	0.39▲	-0.18▼	-0.11▼	-0.13▼	0.06▲	-0.44▼
Björk ∑	0.51▲▲	-0.15▼	-0.12▼	0.24▲	-0.20▼	0.21 ▲	-0.43▼
Go1	0.23▲	0.78▲▲	-0.29▼	-0.60▼▼	-0.31▼	-0.17▼	-0.26▼
Go2	0.65▲▲	-0.10▼	-0.01▼	0.33▲	0.07▲	0.21▲	-0.38▼
S-Go	0.18▲	-0.13▼	0.67▲▲	0.44▲	0.79▲▲	0.20▲	0.27▲
N-Me	0.86▲▲▲	-0.04▼	0.47▲	0.53▲▲	0.50▲▲	0.56▲▲	0.07▲
Index I	-0.50▼▼	-0.04▼	0.22▲	-0.08▼	0.35▲	-0.15▼	0.51▲▲
NL-NSL	0.01▲	-0.10▼	-0.49▼	-0.01▼	-0.54▼▼	0.01▲	-0.31▼
ML-NSL	0.51▲▲	-0.15▼	-0.12▼	0.24▲	-0.20▼	0.21▲	-0.43▼

Where:

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

▼: Negative **weak** strength of correlation, ▼▼: Negative **Moderate** strength of correlation, ▼▼▼: Negative **Strong** strength of correlation.

Cephalometric measurements determining jaws rotation in female subjects showed vary correlation in strength and direction with CBCT measurements of Atlas's dimensions, HIAPC1 have positive correlation with all of CBCT measurements (but vary in strength) excluding the negative correlation with (S),(Ar), and (Index I).

Superior surface have more negative correlation (all its negative correlations were weak excluding correlation with Ar which was negative and strong) except of (S), (Go) and (Go1) which had positive but vary correlation in strength. HOTDC1 also showed more negative correlation (all its negative correlations were only weak) except for its correlation with (Ar), (S-Go), (N-Me), and (Index I) which had positive but vary correlation in strength.

Inner margin, outer margin, LOAPC1, and Height of the atlas dorsal arch showed vary correlation in strength and direction with cephalometric measurements determining jaws rotation (most of this correlations were weak).

The results of Pearson's Correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within male subjects of the sample visually shown in Chart 3

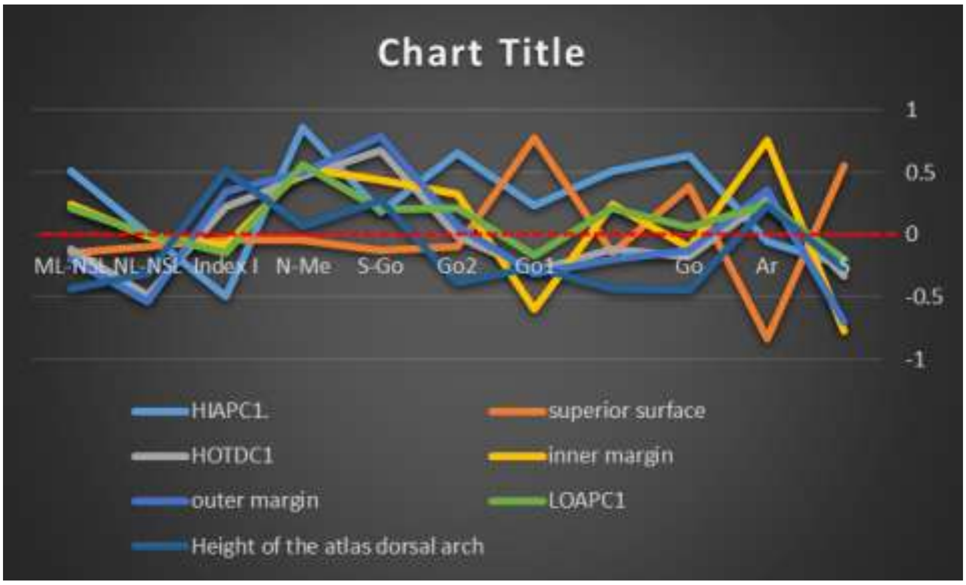

chart 3: Results of Pearson's Correlation between CBCT measurements of Atlas's dimensions and the cephalometric measurements determining jaws rotation (according to Björk and Skieller) within female subjects of the sample.

Female subjects of the sample showed that (N-Me) and (S-Go) have positive direction and vary strength except for (superior surface) of correlation with CBCT measurements, while (S) attending to have more negative direction and vary strength except for (superior surface) of correlation with CBCT measurements, , other cephalometric parameters have vary correlation (in strength and direction) with Atlas's CBCT measurements.

DISCUSSION

The relationship of Atlas's dimensions with jaws rotation in adult orthodontically non-treated subjects has been Comprehensively studied in this investigation.

CBCT measurements of Atlas's dimensions showed no statistical significant differences between the two genders.

This was similar to finding of Grave [34].who reveal that the dorsal arch height of C1 and C2 displayed the greatest dimensional variability in both sexes.

Nevertheless, it was in contrary to results of Nisayif [16] who found a significant difference in the maximum anterioposterior extent of the atlas only. This was also in consensus with Huggare [14], Kylämarkula [35], and Al-Hashimi results [36].

CBCT measurements of Atlas's dimensions having no statistical significant differences between the two genders was also in contrary to Marino's results studying skeletal specimens [37]. Marino found that, the first cervical vertebra could be used as a sex predictor. The one should be note, that Marino's sample include different rang of age (25-70) from our study's age rang, and contain two human races (black and white). This could be the reason of the differences between our results and Marino's results.

This study reveals vary correlation between CBCT measurements of Atlas's dimensions and jaws rotation according to the gender. This was similar to Huggare [13], Liu [15], Nisayif [16], and Sandikçioğlu [38].

Horizontal Inner Anteroposterior Diameter of C1 (HIAPC1) showed within sample's subjects regardless of gender (tab 5, Chart 1) weak negative correlation with jaws rotations except of the moderate positive correlation with Gonial angle and (Go2). This means, in adult subjects, the Horizontal Inner Anteroposterior Diameter of C1 have no significant relationship with jaws rotation. Nevertheless, this study revealed that within sample's subjects (regardless of gender) the more size increasing of the Atlas's Horizontal Inner Anteroposterior Diameter the more increasing of Gonial angle (because of increasing of Lower Gonial angle), and vice versa (tab 5, Chart 1). Anyway, (HIAPC1) in male subjects showed more negative (but almost weak) correlation with jaws rotation (tab 6, Chart 2), whereas in female subjects it showed positive (almost moderate) with jaws rotation (tab 7, Chart 3).

We cannot compare the results of the relationship between the Horizontal Inner Anteroposterior Diameter and the jaws rotation with the previous researches because, these studies were a cephalometric, which mean, the measurements of such anatomical parts in the axial plane were not possible.

Anteroposterior diameter of superior surface of the Atlas's anterior arch (Superior surface) showed within sample's subjects regardless of gender (tab 5, Chart 1) weak negative correlation with jaws rotations except of the moderate positive correlation with (S), (Go1), and a moderate negative correlation with (Ar). This mean, in adult subjects anteroposterior diameter of superior surface of the Atlas's anterior arch have no significant relationship with jaws rotation. Nevertheless, this study revealed that within sample's subjects (regardless of gender) the more size increasing of Anteroposterior diameter of superior surface of the Atlas's anterior arch the more increasing of (S), (Go1) , and the less of the Articular angle (Ar) and vice versa (tab 5, Chart 1).

Anteroposterior diameter of superior surface of the Atlas's anterior arch (Superior surface) in male subjects showed more negative (but almost weak) correlation with jaws rotation (tab 6, Chart 2), this was correct for female subjects also (tab 7, Chart 3).

We cannot compare the results of the relationship between Anteroposterior diameter of superior surface of the Atlas's anterior arch (Superior surface) and the jaws rotation with the previous researches because, these studies were a cephalometric studies, which mean, the measurements of such complex anatomical parts in the axial plane were not conceivable.

Within all sample's subjects regardless of gender (tab 5, Chart 1) Horizontal outer transverse diameter of C1 (HOTDC1) have no statistically significant relationship with the rotational growth of jaws. This was correct also for female subjects (tab 7, Chart 3). (HOTDC1) in male subjects, had strong negative correlation with (Ar), while it was strong positive correlation with (Go1) (tab 6, Chart 2), this possibly played as a compensation factor in decreasing the significance of the relationship of Horizontal outer transverse diameter of C1 with Mandible rotation.

We cannot compare the results of the relationship between Horizontal outer transverse diameter of C1 (HOTDC1) and the jaws rotation with the previous researches because, these studies were a cephalometric studies, which mean, the measurements of such complex anatomical parts in the axial plane were not conceivable.

Within all sample's subjects regardless of gender (tab 5, Chart 1) the minimum transverse diameter of the vertebral canal (inner margin) have almost weak correlation (but vary direction) with jaws rotation except of the moderate negative correlation with (S), (Go1), and a moderate positive correlation with (Ar). Having such weak correlation means that the minimum transverse diameter of the vertebral canal (inner margin) have no significant relationship with jaws rotation. Anyway, in adult subjects regardless of gender, the more size increasing of (inner margin) the less of (S), (Go1) angles, and the more of the Articular angle (Ar) and vice versa (tab 5, Chart 1). This is exactly the opposite behaviour (in adult subjects regardless of gender) of the correlation between Anteroposterior diameter of superior surface of the Atlas's anterior arch (superior surface) and (S, Go1, Ar) angles (tab 5, Chart 1). It has been noted that (inner margin) in male subjects (comparing with female subjects) have stronger but negative correlation with jaws rotations. In fact, (inner margin) in female subjects have no significant relationship with jaws rotation (tab 7, Chart 3); while it have a moderate significant relationship with jaws rotation in male subjects (tab 6, Chart 2).

We cannot compare the results of the relationship between the minimum transverse diameter of the vertebral canal (inner margin) and the jaws rotation with the previous researches because, these studies were a cephalometric studies, which mean, the measurements of such complex anatomical parts in the axial plane were not possible.

Within all sample's subjects regardless of gender (tab 5, Chart 1) the maximum transverse diameter of the anterior part of the Atlas (Outer margin) have a negative moderate significant relationship with upper jaw rotation, but no significant relationship with lower jaw rotation, This was correct also for female subjects (tab 7, Chart 3). In male subjects, the maximum transverse diameter of the anterior part of the Atlas (Outer margin) showed significant moderate negative relationship with jaws rotation (tab 6, Chart 2).

We cannot compare the results of the relationship between the maximum transverse diameter of the anterior part of the Atlas (Outer margin) and the jaws rotation with the previous researches because, these studies were a cephalometric studies, which mean, the measurements of such complex anatomical parts in the axial plane were not possible.

Within all sample's subjects regardless of gender (tab 5, Chart 1), CBCT Atlas measurements that was taken on the sagital plane, showed weak statistically significant relationship with jaws rotation.

Nevertheless, Huggare found that in the groups of low arch of Atlas the gonial angle was more obtuse [14]. This was similar to our finding, although this correlation was weak in our results (tab 5, Chart 1).

On the other hand, Huggare [13] found (in a cephalometric study during a two-year period) a significant correlation between horizontal growth of the mandible and the initial height of the atlas dorsal arch.

Al-Hashimi [36] stated that the mean values of the gonial angle decrease as the atlas dorsal height increase. This was similar to our results, although this correlation was weak in our results (tab 5, Chart 1).

Nisayif (in here cephalometric study) found the higher the dorsal arch is the more the horizontal rotation of the mandible, and vice versa [16]. This was similar to our results, although this correlation was weak in our results (tab 5, Chart 1).

Nisayif also found a significant correlation with mandibular rotation; the higher the dorsal arch and the longer the atlas, is the more the horizontal rotation of the mandible, and vise versa [16]. This was in contrary to our finding (tab 5, Chart 1).

Having no statistically significant relationship between CBCT Atlas measurements that was taken on the sagital plane and jaws rotation was correct also for female subjects (tab 7, Chart 3). This conclusion was in contrary to Liu [15] who found (in Shanghai females between 12 and 15 years old) that, when the atlas size ratio increased, a reduction of the amount of mandibular horizontal growth was showed, and the mandibular rotated backward

Huggare [14] found that, women with low arches showed a steepened mandibular plane, a backward-rotated condylar head, and a decrease in the ratio of posterior to anterior face height. This was similar to our results, although this correlation was weak in our results (tab 7, Chart 3). However, in male subjects (tab 6, Chart 2), CBCT Atlas measurements that was taken on the sagital plane showed more strong and more negative correlation with cephalometric measurements determining jaws rotation, (excepting of Go which had positive correlation. This is identical to the results of Huggare [14] in a study based on macroscopical observations of skeletal material). Nevertheless, in adult male subjects (tab 6, Chart 2), the height of the atlas dorsal arch have weaker correlation with cephalometric measurements determining jaws rotation excepting a negative moderate strength only for (Ar) (the more Height of the atlas dorsal arch the less of Articular angle, and vice versa). This mean a weak statistically significant relationship between the Height of the atlas dorsal arch and the rotational growth of jaws in adult male subjects. Sandikçioğlu [38] found a negative correlation between the height of the posterior arch of atlas and the inclination of the mandible and the maxilla to the anterior cranial base in adult males. However, we found that in adult male subjects (tab 6, Chart 2), the more size increasing of the CBCT Atlas measurements that was taken on the sagital plane, the more Counterclockwise Rotation of upper and lower jaws and vice versa. This was similar to Nisayif results [16]. Positive correlation of (Go) could be explained according to Björk [19, 21, 32] as a kind of compensating rotation growth reaction.

Since (NL-NSL) and (ML-NSL) showed weak correlation with CBCT Atlas measurements (except for the moderate negative correlation of NL-NSL with outer margin) within all sample's subjects regardless of gender (tab 5, Chart 1), the upper jaw rotation and the slope of Mandible's lower border have no statistically significant relationship with CBCT Atlas measurements.

Having weak correlation of (NL-NSL) and (ML-NSL) with CBCT Atlas measurements was also correct for female subjects (tab 7, Chart 3). This was in contrary to Huggare [14] who concluded that, in female with low high arches (posterior and anterior) revealed a steepened mandibular plane, a backward-rotated condylar head, and a decrease in the ratio of posterior to anterior face height.

In male subjects, rotation of upper and lower jaws showed stronger (but only negative) correlation with all CBCT Atlas measurements (tab 6, Chart 2). This mean, in adult male subject: the more size increasing of the CBCT Atlas measurements, the more Counterclockwise Rotation of upper and lower jaws, and vice versa. This was corresponded results of Sandikçioğlu [38] who also found a negative correlation between the height of the posterior arch of atlas and the inclination both of mandible and maxilla to the anterior cranial base in adult males.

Discussing the results of this study, some of our conclusions were in contrary with previous studies, and this may be because:

- Previous studies studying Atlas morphology used lateral cephalometric, which give low quality data because of the image enlargement, and that in one plane only (the sagittal plane) [39]. Whereas the current study used CBCT scan which can produce more high-quality data investigating the detailed morphology of cervical vertebrae in the sagital, frontal, and axial planes with less enlargement comparing with Conventional cephalometry [30, 40, 41, 42]
- Previous studies studying Atlas morphology in different population, which could lead to morphogenetic differences in Atlas measurements. [28].
- It is not possible to find a single factor responsible for direction and motion of the jaws rotation. Individual variations may exist, not only due to morphogenetic factors, but also due to the functional factors.

CONCLUSION

1. CBCT measurements of Atlas's dimensions showed no statistical significant differences between the two genders.
2. This study reveal vary correlation between CBCT measurements of Atlas's dimensions and jaws rotation according to the gender. CBCT measurements of Atlas's dimensions in adult male subjects (comparing with adult female subjects) hade more strong correlation (but vary in strength and direction) with jaws rotations.
3. This study revealed that within sample's subjects (regardless of gender) the more size increasing of the Atlas's Horizontal Inner Anteroposterior Diameter the more increasing of Gonial angle (because of increasing of Lower Gonial angle), and vice versa.
4. Atlas's Horizontal Inner Anteroposterior Diameter in male subjects showed more negative (but almost weak) correlation with jaws rotation, whereas in female subjects it showed positive (almost moderate) with jaws rotation.
5. This study revealed that within sample's subjects (regardless of gender) the more size increasing of Anteroposterior diameter of superior surface of the Atlas's anterior arch the more increasing of (S), (Go1) , and the less of the Articular angle (Ar) and vice versa. Anteroposterior diameter of superior surface of the Atlas's anterior arch in male and female subjects (independently) showed weak negative correlation with jaws rotation, female subjects also showed weak negative. That mean Anteroposterior diameter of superior surface of the Atlas's anterior arch have no statistical significant relationship with jaws rotation.
6. Within all sample's subjects regardless of gender Horizontal outer transverse diameter of C1 (HOTDC1) have no statistically significant relationship with the rotational growth of jaws, although male subjects showed strong negative correlation with (Ar), and strong positive correlation with (Go1).
7. In adult subjects regardless of gender, the more size increasing of (inner margin) the less of (S), (Go1) angles, and the more of the Articular angle (Ar) and vice versa. Anyway, only in male subject it showed a moderate significant relationship with jaws rotation.
8. Within all sample's subjects regardless of gender the maximum transverse diameter of the anterior part of the Atlas (Outer margin) have a negative moderate significant relationship with upper jaw rotation, but no significant relationship with lower jaw rotation, only in male subjects it showed significant moderate negative relationship with jaws rotation.
9. Within all sample's subjects regardless of gender, CBCT Atlas measurements that was taken on the sagital plane, showed weak statistically significant relationship with jaws rotation. However, we found that in adult male subjects, the more size increasing of the CBCT Atlas measurements that was taken on the sagital plane, the more Counterclockwise Rotation of upper and lower jaws and vice versa.
10. the upper jaw rotation and the slope of Mandible's lower border have no statistically significant relationship with CBCT Atlas measurements, though it have been noted in adult male subject a weak association: the more size increasing of the CBCT Atlas measurements, the more Counterclockwise Rotation of upper and lower jaws, and vice versa.

REFERENCES

1. GRAY H. *Anatomy of the Human Body. Philadelphia*: Lea & Febiger, 1918; Bartleby.com, 2000.
2. SCHAFER R.C. *Clinical Biomechanics: Musculoskeletal Actions and Reactions*. (Chapter 25), Williams & Wilkins; 2 Sub edition 1987.
3. FRÄNKEL R. *The applicability of the occipital reference base in cephalometric*. Am J Orthod. 1980 Apr;77(4):379-95.
4. MOSS, M. L. *The primacy of functional matrices in orofacial growth*, Dent. Pract. 19: 65-73, 1968.
5. BJÖRK A. *Cranial base development- A follow-up x-ray study of the individual variation in growth occurring*. A J of O Vol. 41 issue 3 1955.
6. MEW J. *The cause and cure of malocclusion*, Published online: 9 May 2014 | doi:10.1038/sj.bdj.2014.369.
7. GUZAY C.M.*The quadrant theorem*. Doctors Dental Service: Chicago, 1980. Basal Facts 1978; (2)1:187-190.
8. GUZAY C.M.*Quadrant theorem*, TMData Resources 1979.
9. STEFANELLI G.*Craniodonzia: il Sistema Alf*, Ed.Nike 2011.
10. MÜLLER G. *Erkennen und Darstellen des Wachstums an der Synchondrosis spheno-occipitalis nach* Fernröntgenaufnahmen, Fortschr. Kieferorthop. 20: 80-83, 1959.
11. MÜLLER G. *Über die wachstumsbedingten Lageveränderungen von Sella turcica, Nasion und Porion in der Norma lateralis nach* Fernröntgenaufnahmen, Fortschr. Kieferorthop. 20: 204-213, 1959.
12. BIBBY R.E., PRESTON C.B. *The hyoid triangle*. Am J Orthod. 1981 Jul;80(1):92-7.
13. HUGGARE J. *The first cervical vertebra as indicator of mandibular growth*. Eur J Orthod 1989; 11: 10-6.
14. HUGGARE J. *Association between morphology of the first cervical vertebra, head posture, and craniofacial structures*. Eur J Orthod. 1991 Dec;13(6):435-40.
15. LIU H.H, LIN H, SUN Y, TAO L. *A correlate study on the first cervical vertebra and mandibular growth: A comparison of Shanghai females between 12 and 15 years old*. Shanghai Kou Qiang Yi Xue. 1998 Sep;7(3):163-6.
16. NISAYIF DHILAL H. AL SAHAF, NAGHAM H. *The relationship between the morphology of the first cervical vertebra and the direction of mandibular rotation in Iraqi adults* Iraqi Orthod. J. 2005; 1 (2): 32-35
17. BJÖRK A. *Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method*. J Dent Res 1963;42:400-11.
18. BJÖRK A *Prediction of mandibular growth rotation.* AJO-DO 1969 Jun (39-53).
19. BJÖRK A, SKIELLER V. *Facial development and tooth eruption: An implant study at the age of puberty*. AM J ORTHOD 1972; 62:339-83.
20. BJÖRK A. *The role of genetic and local environmental factors in normal and abnormal morphogenesis*. Acta Morphol Neerl Scand 1972;10:49-58.
21. BJÖRK A., SKEILLER V. *Normal and abnormal growth of the mandible: A synthesis of longitudinal cephalometric implant studies over a period of 25 years*. Eur J Orthod 1983;5:1-46.
22. RECK K.B., MIETHKE R.R. *Usefulness of the sum angle according to Björk (Jarabak).* Prakt Kieferorthop.1991 Mar; 5(1):61-4.

23. BARATIERI C, NOJIMA LI, ALVES MJ, SOUZA MMG, NOJIMA MCG. *Transverse effects of rapid maxillary expansion in Class II malocclusion patients: a cone-beam computed tomography study*. Dental Press J Orthod. 2010 set-out; 15(5):89-97.

24. ALVES M JR, BARATIERI C, NOJIMA LI. *Assessment of mini-implant displacement using cone beam computed tomography*. Clin Oral Implants Res. 2011 Oct 22(10):1151-6.

25. AWADALLA A. M., FETOUH F. A. *Morphometric analysis of the vertebral artery groove of the first cervical vertebra (atlas).* Pan Arab Journal Of Neurosurgery. Volume 13, no. 1, April 2009.

26. NADERI S, CAKMAKC¸I H, ACAR F, ARMAN C, MERTOL T, ARDA MN. *Anatomical and computed tomographic analysis of C1 vertebra*. Clin Neurol Neurosurg. 2003;4:245–248.

27. RONALDO GV, MOHRI T, MORITA S, HANADA K. *Cephalometric study on the morphology of the first cervical vertebra to craniofacial structure*. Part 1: Is there any relationship? Niigata Dent J. 1996;26:13–24.

28. HUGGARE J. *Population differences in the morphology of the first cervical vertebra*. Am J Phys Anthropol. 1992 Jun;88(2):197-201.

29. MOSHIRI M., SCARFE W.C, HILGERS M.L, SCHEETZ J.P, SILVEIRA A.M, FARMAN A.G. *Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone-beam computed tomography*. Am J Orthod Dentofacial Orthop. 2007 Oct;132(4):550-60.

30. KUMAR V., LUDLOW J, SOARES CEVIDANES LH, MOL A. *In vivo comparison of conventional and cone beam CT synthesized cephalograms*. Angle Orthod. 2008 Sep;78(5):873-9.

31. LUDLOW J.B., GUBLER M, CEVIDANES L, MOL A. *Precision of cephalometric landmark identification: cone-beam computed tomography vs conventional cephalometric views*. Am J Orthod Dentofacial Orthop. 2009 Sep;136(3):312.e1-10.

32. BJÖRK A. *The face in profile; an anthropological x-ray investigation on Swedish children and conscripts*. Svensktandläkare-Tidskrift. 1947; Suppl. 40. (5B).

33. BJÖRK A, SKIELLER V. LINDE-HANSEN T. *Prediction of mandibular growth rotation evaluated from a longitudinal implant sample.* AJO-DO November, 1984.Volume 86, Number 5.

34. GRAVE B, BROWN T, TOWNSEND G. *Comparison of cervicovertebral dimension in Australian Aborigines and Caucasians*. Eur J Orthod 1999; 21:127-135.

35. KYLÄMARKULA S, HUGGARE J. *Head posture and the morphology of the first cervical vertebra*. Eur J Orthod 1985; 7: 151-6.

36. AL-HASHIMI H.A.H., AL-AZAWI Z.Z. *Association of the Morphology of the Atlas Vertebra with the Morphology of the Mandible*. MDJ.Vol.:5 No.:3 2008

37. MARINO E.A. *Sex estimation using the first cervical vertebra*. Am J Phys Anthropol. 1995 Jun;97(2):127-33.

38. SANDIKÇIOĞLU M., SKOV S, SOLOW B. *Atlas morphology in relation to craniofacial morphology and head posture*. Eur J Orthod. 1994 Apr;16(2):96-103.

39. ATHANASIOU A.E. *Orthodontic Cephalometry*. Mosby-Wolfe London. 1995: 117-6.

40. HOUSTON W.J. *The analysis of errors in orthodontic measurements*. Am J Orthod. 1983;83:382–390.

41. SUKOVIC P. *Cone beam computed tomography in craniofacial imaging*. Orthod Craniofac Res. 2003;6 Suppl 1:31-6; discussion 179-82.

42. WATANABE M., YAMAGUCHI T., MAKI K. *Cervical vertebra morphology in different skeletal classes. A three-dimensional computed tomography evaluation*. Angle Orthod. 2010 Jul;80 (4):531-6.