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Original Investigation

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Is It Necessary to Evaluate the Craniocervical Junction with Computed Tomoghraphy in Adolescent Spinal Deformities?

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ABSTRACT

AIM: To assess the craniocervical junction (CCJ) by using radiological measurements in patients with adolescent idiopathic scoliosis (AIS) and Scheuermann's kyphosis (SK), and to compare those reults with healthy adolescent population.

MATERIAL and METHODS: Patients were assigned to three groups. Group 1 consisted of AIS patients, Group 2 consisted of patients with SK, and Group 3 was the control group who did not have any spinal disorder. The groups were matched based on age and gender. Major Cobb angle and kyphosis angle were measured on X-Ray. asion-axial interval (BAI), basion-dens interval (BDI), posterior atlantodental interval (PADI), anterior atlantodental interval (ADI), atlanto-occipital interval (AOI), and Power's ratio were measured by computerized tomography. The results were compared in each group statistically.

RESULTS: A total of 120 participants, comprised of 78 (65%) female and 42 (35%) male were included in the study. There was no statistically difference between 3 groups based on age and gender ($p>0.05$). According to the measurements, Group 3 had significantly higher PADI measurements than Group 1 ($p=0.01$). The ADI measurements of Group 2 were significantly higher than those of Group 1 and Group 3 ($p=0.01$). Group 3 had significantly higher BDI measurements than Group 1 and Group 2. ($p=0.01$). The Power ratios of Group 1 and Group 3 were statistically higher than that of Group 2 ($p=0.01$). There were no statistically significant differences between the groups in terms of AOI and BAI measurements ($p=0.84$, $p=0.18$, respectively).

CONCLUSION: The presence of AIS and SK may affect the measurement of CCJ, and it may be considered to evaluate instability of the region.

KEYWORDS: Pediatrics, Spinal deformity, Craniocervical junction, Computed tomography, Measurement

ABBREVIATIONS: AIS: Adolescent idiopathic scoliosis, **SK:** Scheuermann's kyphosis, **CCJ:** Craniocervical junction, **CT:** Computed tomography, **BAI:** Basion-axial interval, **BDI:** Basion-dens interval, **PADI:** Posterior atlantodental interval, **ADI:** Anterior atlantodental interval, **AOI:** Atlanto-occipital interval

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) and Scheuermann's kyphosis (SK) are spinal deformities that cannot be fully explained and may be accompanied by additional pathologies that occur cervical changes in both patient groups (13,19). Further radiological examinations for preoperative assessment of patients with AIS and SK are controversial, especially in non-symptomatic patients (2). However, since the embryological and biomechanical development of the Craniocervical Junction (CCJ) differs in subaxial, cervical, and thoracic region (21).

Regarding to the literature, we encountered computer tomography (CT) measurement studies evaluating the CCJ in the adolescent group, but such studies are in limited numbers (1,4,14,22). However, there was no study in the past that investigated the association of AIS and SK with CCJ.

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We believe that further assessment of CCJ in surgical planning may be beneficial. In this study, we aimed to compare the radiological parameters of CCJ in patients with AIS and SK who had scheduled surgery with the adolescent patient who had no spinal disorder.

MATERIAL and METHODS

This retrospective study was performed with the approval of the Institutional Review Board [Fatih Sultan Mehmet Training and Research Hospital (Dec 24, 2019, No.17679)], and in line with the ethical principles of the Declaration of Helsinki.

A total of 120 patients [78 females (65%), and 42 males (35%)] were included in the study between February 2018 and January 2020.

Patients were included in the study between 10 and 16 years old. Patients were divided into three groups: Group 1 consisted of AIS only patients, Group 2 consisted of patients with SK only, and Group 3 (control group) consisted of patients who had no spinal disorder were admitted to the emergency room with suspected head and neck injury.

Patients diagnosed with metabolic or endocrinological disease, previous spinal surgery, intraspinal lesion, diagnosed chromosomal anomaly, congenital spinal deformity, spondyloepiphyseal dysplasia, and patients with head and neck trauma detected to have CCJ or cervical spine pathology in the radiological evaluations of the three-month follow-up period were excluded from the study (Table I).

The groups were matched based on age and gender. Major Cobb angle and kyphosis angle were measured by X-ray. Basion-axial interval (BAI), basion-dens interval (BDI), posterior atlantodental interval (PADI), anterior atlantodental interval (ADI), atlanto-occipital interval (AOI), and Power's ratio were measured by CT in neutral position (cervical collar). (128-slice CT, Optima CT660, General Electric Healthcare Systems, Milwaukee, USA).

The distance from the basion (inferior end of the clivus) to the rostral extension of the posterior axial line (posterior cortical edge of the body C2) was measured as the BAI (Figure 1A) (11).

BDI measurement was calculated by measuring the interval from inferior-most part of the basion to the nearest point of dens superior to the basion (Figure 1A) (25).

ADI was measured between the anterior boundary of the dens and the closest point of the anterior arc of C1 (Figure 1B) (23).

The distance between the posterior margin of the dens and the closest point of the posterior arc of the C1 was measured as PADI (Figure 1B) (8).

Power's ratio refers to the ratio of the distance between the basion and the posterior arch of the atlas (BC) to the distance between the opisthion and the anterior arch of the atlas (AO) (Figure 1C) (12).

AOI was calculated by measuring the average of the interval of the perpendicular line extending from the midpoint of the occipital condyle articular surface in the sagittal and coronal planes to the C1 lateral mass (Figure 1D) (12).

The measurements were made by two experienced spinal surgeon blindly. The accuracy of measurements was within one-tenth of a millimeter.

Statistical Analysis

Statistical analysis was conducted using the SPSS 22.0 package program. Descriptive statistics of the measurements are expressed as frequency, percentage, mean, and standard deviation. Analysis of variance test was used to test the measurements of the study groups. Sidak Paired comparison test was used to determine the group causing the difference in groups. Chi-square test was performed to compare gender and age distribution of the groups. A p value of less than 0.05 was considered as statistically significant.

Calculations of universe-sampling, power level, and effect size calculated in the study were made using G*Power Version 3.1.7.

RESULTS

The sample size of 120 patients included in the study provided a sampling power of 0.90.

Table I: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
10 -16 years of age	Diagnosis of metabolic or endocrinological disease
Diagnosis of adolescent idiopathic scoliosis only or Schuermann's kyphosis only	History of spinal surgery
Patients who were admitted to the emergency department with a pre-diagnosis of head and neck trauma and who did not have fractures or soft tissue injuries according to examination or CT	Intraspinal lesion
	Chromosomal anomaly
	Spondyloepiphyseal dysplasia
	Structural or congenital spinal deformity affecting the cervical region
	CCJ or cervical spine pathology detected in the radiological evaluations in the three-month follow-up period in patients with head and neck trauma

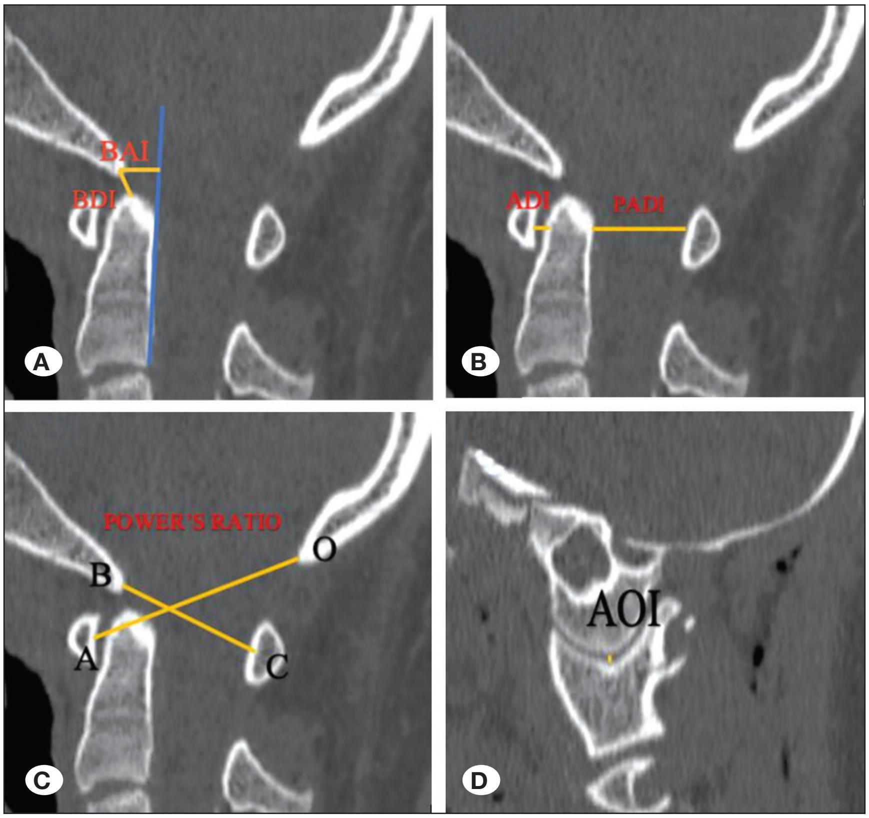

Figure 1: Measurements of; **A)** basion-axial interval (BAI) and basion-dens interval (BDI), **B)** posterior atlantodental interval (PADI) and atlantodental interval (ADI), **C)** Power's ratio, and **D)** atlanto-occipital interval (AOI) in computed tomography scan.

Table II: Demographic Characteristics and Distribution of Patient Groups

	Total n, (%) 120 (100)	Gender		Age Mean±SD (14.35 ± 1.80)	Major Cobb Angle	Kyphosis Angle
		Female n, (%) 78 (65)	Male n, (%) 42 (35)			
Group 1	38 (31.7)	25 (65.7)	13 (34.3)	14.02 ± 2.23	54.08 ± 12.39	-
Group 2	36 (30.0)	24 (66.7)	12 (33.3)	14.47 ± 1.76	-	79.87 ± 5.05
Group 3	46 (38.3)	29 (63.1)	17 (36.9)	14.63 ± 1.07	-	-
p		0.11*		0.78**		

***, **:** *There was no statistically difference based on age and gender between 3 groups.*

Table III: Intraobserver and Interobserver Reliability

Measurement	Among Assessors	Between Assessors	
		Assessor 1	Assessor 2
PADI	0.93 (88)	0.90 (88)	0.91 (87)
ADI	0.92 (87)	0.89 (87)	0.89 (86)
BDI	0.90 (86)	0.87 (85)	0.88 (87)
BAI	0.92 (87)	0.89 (88)	0.87 (86)
AOI	0.93 (88)	0.90 (87)	0.89 (88)
Power's ratio	0.90 (86)	0.87 (85)	0.86 (86)

**r and (%) consistency.*

Table IV: Investigation of the Relations between Groups and Measurement Values

	BAI	BDI	ADI	PADI	AOI	Power's Rario
Group 1	3.97 ± 1.79	5.77 ± 1.56	2.19 ± 0.51	18.90 ± 1.88	1.20 ± 0.09	0.79 ± 0.11
Group 2	3.69 ± 2.33	5.42 ± 1.87	2.66 ± 0.79	19.89 ± 1.86	1.22 ± 0.08	0.72 ± 0.07
Group 3	3.86 ± 1.83	6.53 ± 1.47	2.17 ± 0.60	20.01 ± 1.76	1.35 ± 1.69	0.81 ± 0.08
p	0.84	**0.01***	**0.01***	**0.01***	0.658	**0.01***
Difference		3>1.2 1=2 **(p=0.01)** 2=1 (p=0.26)	2>1.3 **(p=0.01)** 1=3 (p=0.59)	3>1 **(p=0.01)** 3=2 (p=0.12) 2=1 (p=0.07)		1.3>2 **(p=0.01)** 1=3 (p=0.41)

***Analysis of Variance is used. *Significant difference, ***Sidak paired comparison test.*

The mean age of the Groups were 14.02 ± 2.23, 14.47 ± 1.76, 14.63 ± 1.07, respectively.

There was no statistically difference based on age and gender between 3 groups (p=0.76) (Table II). The measurements made by 2 experienced surgeons were found to be consistent both in general and among the groups (p>0.05) (Table III).

The mean Cobb angle of Group 1 was 54.08° ± 12.39° and kyphosis angle of Group 2 was 79.87° ± 5.05°. The measurement by CT scan of mean PADI, ADI, BDI, BAI, AOI, and Power ratio were shown on Table IV. Group 3 had significantly higher PADI measurements than Group 1 (p=0.01). Group 2 were significantly higher ADI than those of Group 1 and Group 3 (p=0.01). Group 3 had significantly higher BDI than Group 1 and Group 2. (p=0.01). The Power's ratios of Group 1 and Group 3 were statistically higher than that of Group 2 (p=0.01). There were no statistically significant differences between the groups in terms of AOI and BAI measurements (p=0.84, p=0.18, respectively) (Table IV).

DISCUSSION

According to the results of our study, we found that there were changes in the radiological parameters evaluating by CT scan in the CCJ region of the patients with surgery planned for AIS and SK. These changes may be considered for CCJ instability compared to the adolescent patient with no spinal disorder.

CCJ instability is more common in the pediatric age group and the etiology is multifactorial. Its occurrence only after isolated trauma is very rare. Congenital causes such as Down's syndrome and Goldenhar syndrome (5), skeletal dysplasia (6) and spondyloepiphyseal dysplasia (10,15) may cause CCJ instability. In the present study we had no patient with syndrome or congenital spinal disorder that may change our conclusion.

CT is a superior imaging method compared to the x-ray in evaluating bone structure and its sensitivity is between 95-100% (4,7). In the 2019 revision of the American College of Radiology Appropriateness Criteria of suspected pediatric cervical spinal trauma, the panel of experts rated cervical CT as an acceptable alternative to radiographs in the initial evaluation of cervical spine trauma in pediatric patients aged 3 - 16 years (16). Therefore, in our study, we used the measurement of CT scan for a more reliable evaluation than X-ray regarding to the literature.used the measurement of CT scan for a more reliable evaluation than X-ray regarding to the literature.

In their study in 89 patients aged 6 months - 17 years, Pang et al. determined that the upper BDI limit was 12 mm (20), while Vachhrajani et al. reported it was 7.49 mm in a sample of 42 patients aged 1 month -18 years (22). In our study, we found that the mean BDI distance of all groups was shorter that the literature data. It was observed that the BDI distance of the control group was shorter than AIS and SK groups.

Aktürk and Ozbal Gunes reported that a mean ADI of 1.6 mm in a group of 120 healthy children aged 11-15 years (1), while Bertozzi et al. reported that ADI should be less than 2.6 mm in their study of 117 healthy children between 4 months and 8 years of age (4). In our study, we found thatthe mean ADI distance of all groups was shorter that the literature data.It was observed that the ADI distance of the control group was significantly longer than the control group.

There is a common opinion in healthy pediatric age population in the literature that the Power's ratio should be between 0.7 and 1 (4,9). In our study, it was found that the Power's ratios of the groups were compatible with the literature. In our study, we found thatthe mean ADI distance of all groups was shorter that the literature data. Although our results appear to be within the reference range in the literature, there are some differences. It was determined that the Power's Ration ratio of the SK group was close to the lower limit of the reference range and was lower than the control group.

The only CT study that assessed PADI was conducted by Vachhrajani et al. and they determined the average length as 18.3 mm. However, they argued that an ideal distance cannot be reliably set due to the wide range of PADI measurements (22). In our study, we found that the PADI distance of the control group was longer than the other groups, and that the PADI distances of the patients with AIS were shorter than the other groups.

CT measurements of the CCJ region have been performed in previous studies on patient populationsincluding the pediatric age group. The fact that our study was conducted in the adolescent age group is likely to differ in BDI, PADI, ADI, and Power's ratio.

These differences may be due to various reasons. Foremost, it is argued that ADI, BDI, and Power's ratio measurements may produce different results depending on whether there is terminal ossification, so they may differ the parameters of measurement (1,4). As for other reasons, bone development in different stages may be a factor in patients with AIS and SK compared to their healthy population (3,17,18). However, there is no common consensus in the literature regarding to this subject. Furthermore, vertebral body development occurs later than posterior elements in SK (24). Hence, changes in the cervical vertebrae of the patients in SK and AIS groups may also be the cause for previous reasons regarding to the literature.

In a radiological CT study on BAI measurement, although the age range was 0-8 years and the average length was 3.4 mm. Therefore, the authors reported that the measurement was not reliable and faulty since it was made over a line drawn tangent to the posterior of the dens (4). The results of our study reported that the margin of error was not as much as it was suggested since there was a high level of consistency among the surgeons, although the results herein were similar to those reported in the literature.

In their studies evaluating AOI, Pang et al. reported the mean AOI as 1.33 mm (20), while Bertozzi et al. reported 1.6 mm (4). We found that the results of our study were consistent with the literature. Moreover, the literature did not define any factors that affect the measurement of AOI. In light of theour study, it can be maintained that it is a consistent measurement parameter regarding to our results.

Our study had some limitations. The first limitation of our study was the retrospective design. In addition, although we tried to make the gender distribution balanced, due to the low number of patients, we could not create a subgroup of male and female genders, who enter the rapid growth phase in different age ranges. Because it is difficult to encounter an isolated patient in which both deformities are present within surgery planned. Despite of this limitation, in our study we matched the gender of the groups and there was no statistically difference between the groups. The ideal control group should include cervical CT scans, performed on healthy individuals without any cervical and head trauma, but this is unlikely to be implemented in practice. In terms of the literature, CT scan is the most reliable radiological measurement in the CCJ evaluation. We included the trauma patients only who had CT scan mandatory to avoid the radiation damage.

The present study bears significance as it is the first study on this subject. We believe that our study may provide the way for further extensive and comprehensive studies.

CONCLUSION

In conclusion, the results of our study indicated that the presence of AIS and SK may affect the measurement of CCJ. Extra caution should be taken for cervical region who may have CCJ instability in this patient group.

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