Check for updates

Received: 13 March 2023 | Revised: 30 May 2023 | Accepted: 28 October 2023

DOI: 10.1111/joor.13622

ORIGINAL ARTICLE

JOURNAL OF ORAL REHABILITATION WILEY

The effect of temporomandibular joint dysfunction on the craniocervical mandibular system: A retrospective study

Kübra Öztürk[1] | Hikmetnur Danışman[2] | Fatma Akkoca[3]

[1]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Nuh Naci Yazgan University, Kayseri, Turkey

[2]Department of Orthodontics, Faculty of Dentistry, Nuh Naci Yazgan University, Kayseri, Turkey

[3]Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Nuh Naci Yazgan University, Kayseri, Turkey

Correspondence
Kübra Öztürk, Nuh Naci Yazgan Üniversi Yerleşkesi Diş hekimliği Fakültesi, Erkilet dere mah, Kuzey çevre yolu, Kayseri, Turkey.
Email: kbrozturk89@gmail.com

Abstract

Background: Temporomandibular disorders are the most common condition affecting the orofacial region, resulting in pain and dysfunction.

Objective: This study aimed to elucidate the ambiguous association between cervical features and temporomandibular disorders by measuring the rotations between the skull-atlas, atlas-axis and mandible-atlas and examining the relationship between these rotations and temporomandibular disorders.

Methods: Cone-beam computed tomography (CBCT) images from 176 patients, 97 females and 79 males with an average age of 25.7 years were used in this study. The patients were divided into two groups: those with joint dysfunction ($n = 88$) and those without ($n = 88$). The study employed various methods to determine rotations in the skull-atlas, atlas-axis and mandible atlas based on anatomical landmarks and measurements. These methods include the use of specific planes, angles and distances to identify and measure rotation. Data analysis was performed using the TURCOSA statistical software (Turcosa Analytics Ltd Co, Turkey, www.turcosa.com.tr).

Results: The results showed that the degree of rotation between the skull and the atlas was higher in the TMD group than in the control group ($p < .001$). Similarly, Atlas-axis rotation was significantly higher in the TMD group ($p < .001$). However, no significant difference was found between mandible atlas rotations in the two groups ($p = .546$). The study also found a significant difference between the direction of rotation between the atlas and axis and the direction of mandible atlas rotation ($p < .001$) as well as between skull and atlas rotations and mandible-atlas rotations ($p < .001$).

Conclusion: Overall, the study suggests that there is a relationship between the skeletal structures of the cranio-cervico-mandibular system and TMD. Skull-atlas and atlas-axis rotations may play an important role in the aetiology of TMD in individuals with TMD. Therefore, it is important to evaluate rotations in the skull-atlas-axis region for the treatment of TMD.

KEYWORDS
atlas, axis, cervical, mandible, temporomandibular joint disorder, vertebra

 © 2023 John Wiley & Sons Ltd.

1 | INTRODUCTION

Temporomandibular disorders (TMD) are prevalent conditions affecting the orofacial region, resulting in pain and dysfunction. The pathophysiology of TMD is multifactorial and involves complex interactions among physical, biochemical and psychological factors. Recent research has suggested that cervical dysfunction may also contribute to the aetiology of TMD.[1] TMJ is connected to the cervical region through muscles and ligaments, providing a functional complex known as the 'craniocervical mandibular system' that offers neurological and biomechanical interactions between the skull, mandible and cervical spine.[2] The C1–C2 joint, known as the atlantoaxial joint, performs critical movements that allow for delicate actions in daily life. Abnormalities in craniocervical alignment may contribute to the development and progression of TMJ dysfunctions.[2–6] A review study has shown that there may be a correlation between cranio-cervical postures, such as cranio-cervical angulation, incorrect alignment of the first (C1) and second cervical vertebrae (C2), and temporomandibular joint (TMJ) dysfunction.[5,6] The reciprocal relationship between head posture and jaw function involves the stomatognathic triad, including occlusion, temporomandibular joint and the neuromuscular system.[7] Skeletal pattern, head posture and TMD's connection remain controversial, although physical and functional connections between the cranial area, temporomandibular joint, cervical spine and hyoid bone have been established.[6,8–14]

Providing both condylar and occlusal stability reduces the risk of TMD. This justifies the need for an orthopaedic strategy to treat TMD patients. The association between the TMJ and the head and neck area should be assessed to include an appropriate orthopaedic approach and physical therapy rehabilitation in treatment.[15] Although it is known that TMD is a complex disorder involving multiple factors in their aetiology, it is still unclear whether cervical dysfunctions are truly effective in the aetiology of TMD.[6,8]

This study aimed to investigate the relationship between the skull, atlas, axis and mandible in individuals with and without temporomandibular joint problems to shed light on the uncertain connection between cervical characteristics and TMD.

2 | MATERIALS AND METHODS

2.1 | Sample selections

This study involved 176 cone-beam computed tomography (CBCT) images collected between January 2020 and August 2022 at the Faculty of Dentistry, Nuh Naci Yazgan University. This study was approved by the Ethics Board and Commissions of Nuh Naci Yazgan University, Kayseri, Turkey (2023/001-004).

2.2 | Criteria for inclusion and exclusion

In this study, CBCT images of patients aged >18 between the years 2020 and 2023 were used. Patients under 18 years of age and with poor image quality or artefacts were excluded from CBCT images.

In our clinic, DC/TMD diagnostic criteria are used to evaluate orofacial pain. Patients were asked to complete a TMD pain screener, symptom questionnaire, demographics from Axis I, pain drawing, graded chronic pain scale, jaw functional limitation scale-20 and patient health questionnaire-9 from Axis II. The clinical examination form is completed by the doctor, and the examination is completed. DC/TMD: Diagnostic movies were obtained using a diagnostic decision tree. Accordingly, bilateral temporomandibular joint tomography is required to confirm the preliminary diagnosis of degenerative joint disease. This study included patients with confirmed degenerative joint disease. Patients who had pain in the neck and back region on Axis II: Pain drawings were excluded from the study. For the control group, patient data were selected for those who had no complaints of pain in the TMJ, head, neck and back regions and showed no dysfunction in the TMJ during clinical examination, and who had received CBCT for implant treatment or extraction of impacted third molars. Patients who had previously undergone orthodontic or temporomandibular joint treatment, experienced trauma or had congenital craniofacial anomalies were excluded from the study.

2.3 | Acquisition of images

All the CBCT scans were performed by the same X-ray technician. During the X-ray, the patient was standing, with maximum intercuspidation, the head in a neutral position, the midline centred and the horizontal plane parallel to the canto-meatal plane. 3D digital imaging equipment (KaVO OP 3D Pro, PaloDEx Group Oy, Tuusula, Finland) with a predetermined protocol and parameters were used to obtain CBCT images. The tomographic KaVO OP 3D Pro CBCT scanner was set up as follows: the exposure settings used in this investigation for the selected saved photos were as follows: field of view (FOV) of 13 × 15 cm; (ii) exposure setting of 90 kV, 08 mA, (iii) exposure time—17.5–26.9 s and (iv) voxel size, 0.320 mm.

2.4 | Image analysis

OnDemand 3D Imaging Software (Cybermed) was used for image reconstruction measurements. Slicing was performed at both the cranial base and cervical vertebral level, with a thickness of 1 mm in the acquired images.

2.5 | Determination of rotations

2.5.1 | Skull-atlas

The plane passing through the opisthion and nasion points, as described by Hayeck et al., was also used in our study to define the midline.[16] To identify the midline of the atlas, we employed the method

13652842, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joor.13622 by Dokuz Eylul University, Wiley Online Library on [20/11/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

used by Galli et al., which involves a horizontal plane passing through the anterior margin of the foramen transversarium with a vertical line perpendicular to this plane at a 90° angle.[17] Subsequently, the angle between the vertical line and midline passing through the nasion was calculated (Figure 1).

2.5.2 | Atlas-axis

In coronal sections, the distances from the cortical bone border of the dens axis to the cortical bone border of the foramina transverse of the atlas were measured on both the right and left sides. The direction of rotation was recorded on the side with the longest distance. If the right and left distances were equal, then no rotation was considered. The difference between the distances on the right and left sides indicates the presence of rotation regardless of the direction. The difference between the two distances was calculated by subtracting the smaller distance from the larger one. This was interpreted as an increase in rotation as the difference between the two distances increased (Figure 2).[18]

2.5.3 | Mandible-atlas

The mandibular plane was employed as a reference point to investigate the relationship between the transfer planes tangential to the posterior mandibular rami and the transverse plane passing through the anterior foramina, transverse to the atlas. Rotation was determined towards the side to which the transverse plane of the atlas was inclined (Figure 3).[17]

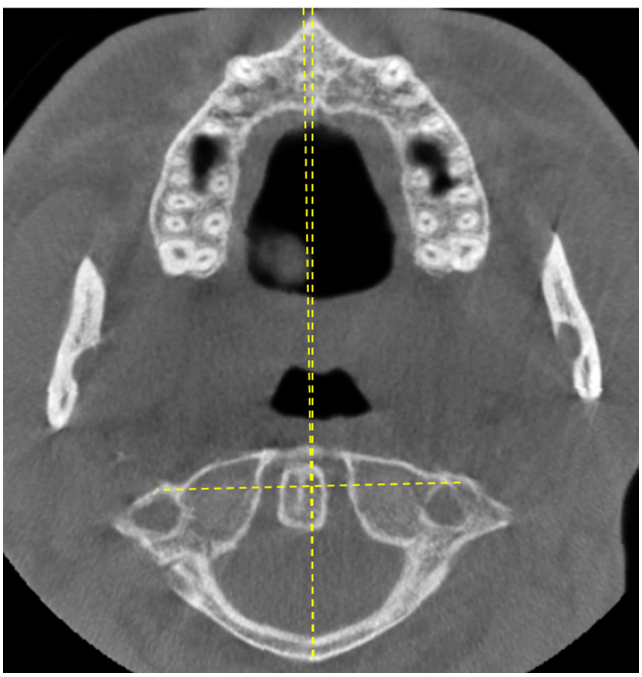


FIGURE 1 Reference planes and angle calculation method used to determine the relationship between the skull reference point (Nasion) and the atlas (C1).

2.6 | Statistical analysis

The sample size was determined using GPower 3.1.9.7. The effect size was determined using the study by Galli et al.[17] The sample size was determined to be 176 based on an effect size of 0.5, power of 0.95 and $\alpha = 0.05$. In the joint-diagnosed patient group, 88 CBCT images were analysed, and 88 were analysed in the control group. Data analysis was performed using TURCOSA (Turcosa Analytics Ltd Co,

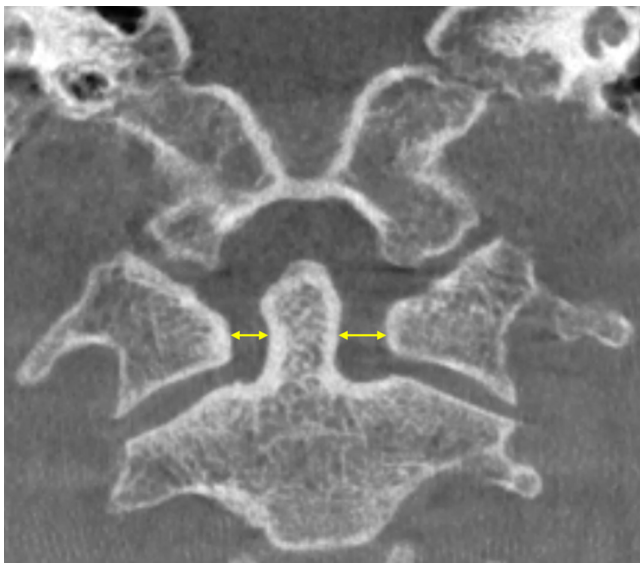


FIGURE 2 Reference lengths in determining the relationship between atlas (C1) and axis (C2).

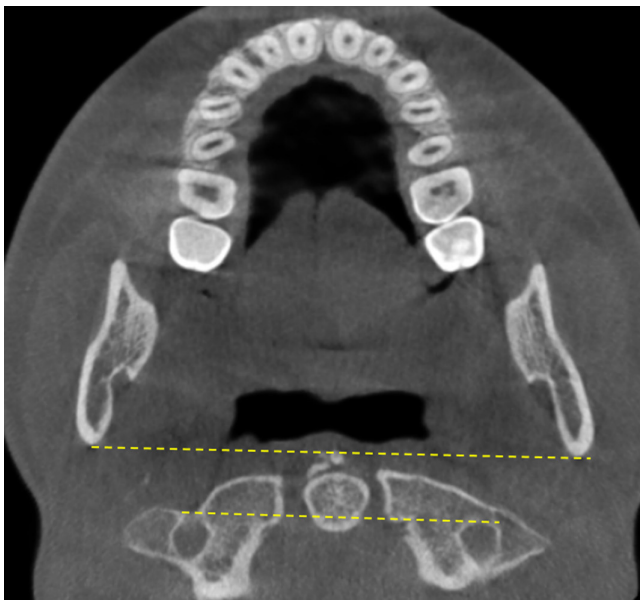


FIGURE 3 Reference planes that determine the relationship between atlas and mandible.

13652842, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joor.13622 by Dokuz Eylul University, Wiley Online Library on [20/11/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

www.turcosa.com.tr) statistical software. Descriptive statistics were used for quantitative variables. The normality of the data was assessed by the Shapiro–Wilk normality test and Q-Q graphs. Normally distributed data are presented as mean ± SD, whereas non-normally distributed data are presented as median (minimum–maximum). The Mann–Whitney *U* test was used to compare non-parametric variables between independent paired groups. Frequency analysis was used for qualitative variables. The chi-square test was used to examine the relationship between the qualitative variables. A statistical significance level was considered $\alpha < 0.05$.

2.7 | Examiner consistency

Ten randomly selected images were observed again by a dentomaxillofacial radiologist 2 weeks after the first round of observation. Examiner consistency was assessed for all the variables. The variables were highly similar between the first and second rounds of observation, with the correlation coefficients of 0.85–0.96.

3 | RESULTS

CBCT images of 97 (55.1%) female and 79 (44.9%) male patients were analysed in this study. Of the cranial atlas rotations, 84 (47.7%) were to the left and 92 (52.3%) were to the right. Regarding the atlas-axis, 73 (41.5%) patients had left rotation, 80 (45.5%) had right rotation and 23 (13%) had no rotation. In the mandible-atlas rotations, 84 (47.7%) were to the left and 92 (52.3%) were to the right (Table 1).

The age of the patients ranged from 18 to 45 years, with an average of 25.7 ± 6.5. The average age of patients in the control group was 25.6 ± 6.3, whereas the average age of patients with TMD was 25.9 ± 6.7. The degree of rotation between the skull and the atlas showed an average of 1.3 ± 0.90 to the left and 1.74 ± 1.70 to the right. When we examined the distance from the right and left cortical limits of the dens axis to the closest boundary to the foramen of the atlas, we found the right distance to be 4.1 ± 1 mm and the left distance to be 4.2 ± 1 mm (Table 2).

The relationship between the skull and the atlas vertebra was examined in the TMD group and compared with that in the control group. Angle measurements on the right and left sides were obtained and compared between the two groups. For all three measurements, the angle values were higher in the TMD group than those in the control group. Specifically, in left-sided data, the TMD group (1.3) had a significantly higher grade than the control group (0.8; $p = .003$). Similarly, in the right-sided data, the TMD group (2) had a significantly higher grade than the control group (0.65; $p < .001$). Moreover, regardless of direction, the angle in the TMD group (1.5) was significantly higher than that in the control group (0.7; $p < .001$; Table 3).

In the comparison of the groups in which the rotation between the atlas and axis vertebrae was examined, the difference in distance in the TMD group (0.6) was found to be significantly higher than that in the control group (0.2; $p < .001$), indicating a greater degree of atlas-axis rotation in the TMD group (Table 3). Comparing the presence and direction of rotation between the atlas-axis vertebrae in both groups, the TMD group had a significantly higher rotation than the control group ($p = .007$, $\chi^2 = 9.8115$; Table 4). The mandible-atlas rotations did not show a statistically significant difference between the diagnoses ($p = .546$, $\chi^2 = 0.3644$; Table 4).

There was a statistically significant difference between the direction of rotation between the atlas and axis and the direction of mandible-atlas rotation ($p < .001$*, $\chi^2 = 78.5651$). There was also a

TABLE 1 Distribution of data according to various variables.

	N	%
Gender		
Female	97	55.1
Male	79	44.9
Diagnosis		
Control (*n*: 88)	88	50
TMD (*n*: 88)	88	50
Skull-atlas rotation		
Left (*n*: 84)	84	47.7
Right (*n*: 92)	92	52.3
Atlas-axis rotation		
Left	73	41.5
Right	80	45.5
None	23	13
Mandible-atlas rotation		
Left	84	47.7
Right	92	52.3
Total	176	100

TABLE 2 The distribution of the mean age of the research group according to different variables, the angles between the skull and the atlas and the distance of the atlas-axis relative to the dens axis.

	Age mean ± SD (min–max)
Gender	
Female (*n*: 97)	26.7 ± 6.3 (18–41)
Male (*n*: 79)	24.6 ± 6.5 (18–45)
Diagnosis	
Control (*n*: 88)	25.6 ± 6.3 (18–45)
TMD (*n*: 88)	25.9 ± 6.7 (18–45)
Total	25.7 ± 6.5 (18–45)
Skull-atlas	**Angle (0) Mean ± SD (min-max)**
Left (*n*: 84)	1.3 ± 0.9 (0.1–5.4)
Right (*n*: 92)	1.74 ± 1.7 (0.1–9.1)
Atlas axis	**Distance (mm)**
Right distance (*n*: 176)	4.1 ± 1 (2–7.4)
Left distance (*n*: 176)	4.2 ± 1 (2–8.4)

13652842, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joor.13622 by Dokuz Eylul University, Wiley Online Library on [20/11/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 3 Angle distribution comparison between control and TMD diagnosis categories.

	Diagnosis		
	Control	TMD	*p* value*
Skull-atlas rotation			
Left	0.8 (0.1–3)	1.3 (0.2–5.4)	.003
Right	0.65 (0.1–4.7)	2 (0.3–9.1)	<.001
Total	0.7 (0.1–4.7)	1.5 (0.2–9.1)	<.001
Atlas-axis rotation			
Difference of distances	0.2 (0–2.7)	0.6 (0–2.9)	<.001

*Mann–Whitney *U* test.

TABLE 4 Comparison of rotations between mandible-atlas according to diagnosis.

	Diagnosis		
	Control	TMD	Chi-square test
Atlas-axis rotation			
Left	37 (21)	36 (20.5)	$p=.007$* $\chi^2=9.8115$
Right	33 (18.8)	47 (26.7)	
None	18 (10.2)	5 (2.8)	
Mandible-atlas rotation			
Left	44 (25)	40 (22.7)	$p=.546$ $\chi^2=0.3644$
Right	44 (25)	48 (27.3)	

*$p<.05$.

statistically significant difference between the skull-atlas and mandible-atlas rotations ($p<.001$*, $\chi^2=176$; Table 5, Figure 4).

4 | DISCUSSION

This study aimed to investigate the relationship between the skeletal structures of the cranio-cervico-mandibular system, specifically skull and atlas rotation, as well as the atlas-axis and mandible-atlas rotations, in patients with and without TMD. This was achieved by analysing CBCT images, which showed that the degree of rotation between the skull and atlas was higher in the TMD group than in the control group. The TMD group also showed a greater degree of atlas-axis rotation than did the control group. There was no significant difference in mandible-atlas rotation between the two groups. Galli et al., in their study evaluating the rotations of the mandible and atlas, stated that mandible-atlas rotation in the axial plane was present in all patients participating in the study and that these anatomical structures were not perfectly aligned in the frontal plane in any case. They also stated that the rotations of the mandible and atlas were in the same direction in 80.98% of the patients.[17] In our study, similar to this study, it was shown that there were rotations in the axial plane between the mandibulo-cranio-cervical bones in both groups with and without TMD; thus, there were differences

TABLE 5 Comparison of atlas-axis and skull-atlas rotations with respect to mandible-atlas rotations.

	Mandible-atlas rotation		
	Left	Right	Chi-square test
Atlas-axis rotation			
Left	63 (35.8)	10 (5.7)	$p<.001$* $\chi^2=78.5651$
Right	12 (6.8)	68 (38.6)	
None	9 (5.1)	14 (8)	
Skull-atlas			
Left	84 (47.7)	0 (0)	$p<.001$* $\chi^2=176$
Right	0 (0)	92 (52.3)	

*$p<.05$.

in the alignment between the bones. However, the rotation angle values between the skull-atlas and atlas-axis bones of patients with TMD were significantly higher than those in the control group. This shows that the craniocervical posture of patients with TMD was more affected than that of patients without TMD. The reason why the mandible-atlas rotation was similar in the groups with and without TMD is thought to be that both rotate in the same direction, as stated by Galli et al. In our study, rotation was evaluated by measuring the angle between the mandible and atlas; therefore, the angle formed between them may not have changed much because the rotation directions were the same. Furthermore, our study is the first to compare rotations of individuals with and without TMD.

Hulse and Lossert-Bruggner suggested that if a temporomandibular joint disorder leads to pathological changes in the head joint, then a functional disorder in the head joint region can also result in temporomandibular joint disorder.[19] Flores et al. examined possible relationships between various craniocervical parameters and TMD in their study in 2016 and as a result, they presented the conclusion that 'there is a relationship between the anatomical and functional parameters of the cervical spine in TMD patients'.[20] Based on this information, we investigated the relationship between the cervical spine position in patients with and without TMD. We found that the skull-atlas angle and atlas-axis rotation increased in patients with TMD, which is consistent with the literature. To determine the cervical spine positions, the reference point was established as the vertical line passing through the fixed-point nasion of the skull. The advantage of this plane is its ability to confirm its passage through the nasion using a horizontally oriented plane parallel to the Frankfurt plane.[16] The transverse line from the anterior border of the foramina was used as a reference along the spinal axis. The study by Galli et al., which is the first study in the literature to examine this subject using CBCT, served as a reference for determining these points.[17] However, lateral cephalometric evaluations have demonstrated a correlation between cervical posture and occlusion.[21] Moreover, it has been established that the C1–C2 distance measured using lateral cephalometry varies between individuals with and without TMD.[22] An et al. observed that craniocervical posture was significantly influenced by temporomandibular joint (TMJ) disc displacement, which

13652842, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joor.13622 by Dokuz Eylul University, Wiley Online Library on [20/11/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

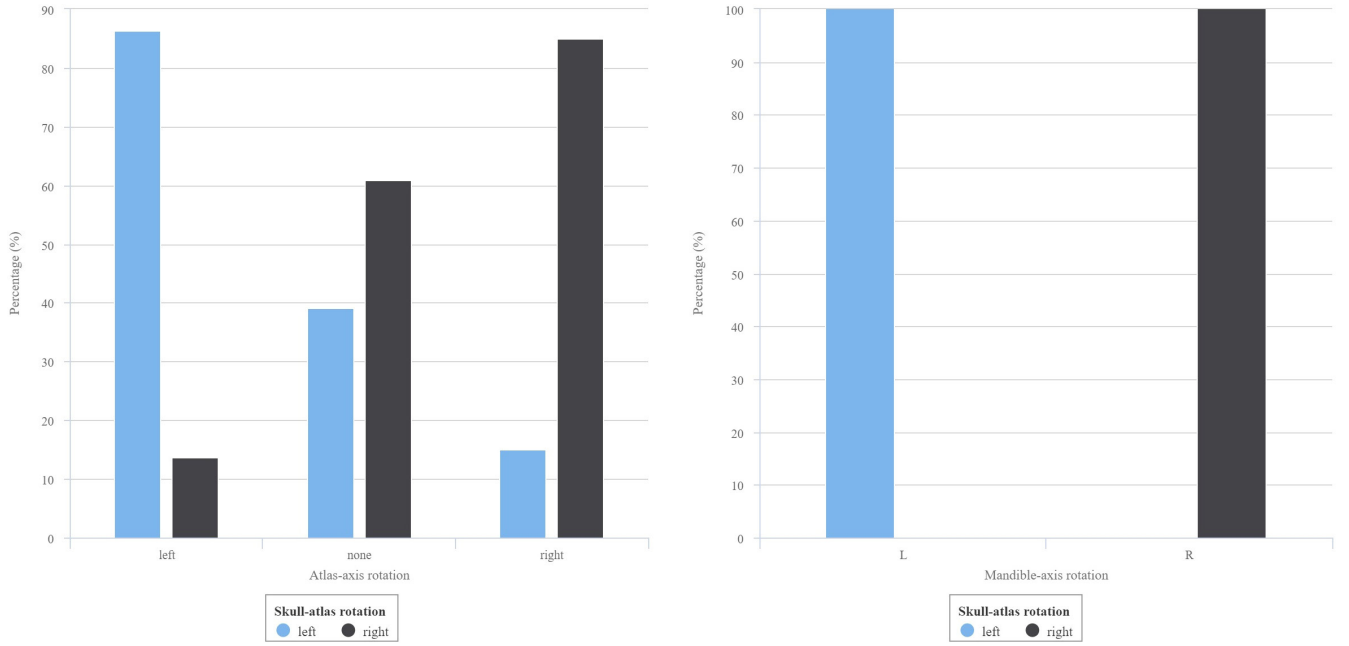


FIGURE 4 Graphical representation of the relationship of skull-atlas data between atlas-axis and mandible axis.

may be linked to a hyperdivergent skeletal model characterised by a retrognathic mandible,[23] whereas Camara-Souza et al. did not find any relationship between craniocervical posture in the sagittal plane and the presence of TMD.[24]

While lateral radiographs enable the evaluation of posture, CBCT was favoured in our study because of its ability to examine posture along three different axes. In our study, the coronal section was used to assess the relationship between the atlas and axis, whereas the axial section was used to examine the relationship between the mandible and the atlas. Ekici and Camcı stated that TMD is not associated with craniocervical posture but rather with the position of the hyoid bone and craniofacial morphology.[25] Previous studies have generally evaluated posture by measuring the craniocervical angle in the sagittal plane on lateral radiographs. However, the concept of posture encompasses the arrangement and alignment of the skeletal system in all three dimensions of space. Therefore, based on the belief that the skeletal system needs to be examined in all three dimensions of space, we chose different cross-sectional images to investigate the alignment and relationship between the mandible and vertebrae in the transverse plane in patients with TMD. This approach contributes to the novelty of the literature.

Occlusion is a major aetiological factor of TMD.[26] Westersund et al. posited that there may be a connection between the craniocervical junction and occlusal contacts.[27] Arntsen and Sonnesen reported a correlation between head and neck postures and various craniofacial features. They observed a relationship between the length of the mandibular body, mandibular divergence and the angle of the cranial base or direction of facial growth.[28] Bedoya et al. indicated that there are correlations between cranial base structures, maxilla, mandible and cervical vertebrae in CBCT images of young patients with Class 2 Division 1 occlusion.[12] In our study, we did not differentiate between the skeletal features and occlusion types in patients with TMD. Instead, we only evaluated whether the patients were diagnosed with TMD based on the DC/TMD. Our results indicated that there was no significant difference in the relationship between the mandible and the atlas in patients with TMD.

Several measuring techniques are required in many planes to fully comprehend the anatomical and physiological complexity of the craniofacial area as well as the changes related to the craniocervical components.[29] However, an MR study investigating the association between craniocervical disorders and TMD suggested that the relationship may be related to the muscular component rather than the joint component.[9]

The limitations of this study include the lack of sufficient data to enable analysis based on different occlusion types. The increase in the angle between the skull and atlas in patients with TMD suggests a potential relationship that may have important implications for diagnosis and treatment. CBCT examinations are infrequent in the literature. Based on this, there is a need for more comprehensive, multi-centre studies that utilise both CBCT and MRI to better understand the complex growth and development process of the craniocervical-facial region and the relationship between its components.

5 | CONCLUSION

This study showed that the craniocervical posture of patients with TMD was more affected than that of patients without TMD. Our study also highlights the importance of examining the skeletal system in all three dimensions of space, as different cross-sectional images were used to investigate the alignment and relationship between the mandible and vertebrae in the transverse plane in patients with TMD. Despite these limitations, our findings add to the existing literature on the relationship between craniocervical posture and TMD.

13652842, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joor.13622 by Dokuz Eylul University, Wiley Online Library on [20/11/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest and that they did not receive funds for this investigation.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/joor.13622.

DATA AVAILABILITY STATEMENT

The datasets created and analyzed during the current studyare available from the corresponding author upon request.

ORCID

Kübra Öztürk https://orcid.org/0000-0003-4447-0103
Hikmetnur Danışman https://orcid.org/0000-0002-4203-2575
Fatma Akkoca https://orcid.org/0000-0002-4522-656X

REFERENCES

1. Rezaie K, Amiri A, Ebrahimi Takamjani E, Shirani G, Salehi S, Alizadeh L. The efficacy of neck and temporomandibular joint (TMJ) manual therapy in comparison with a multimodal approach in the patients with TMJ dysfunction: a blinded randomized controlled trial. *Med J Islam Repub Iran*. 2022;36:45.
2. Ferrillo M, Marotta N, Giudice A, et al. Effects of occlusal splints on spinal posture in patients with temporomandibular disorders: a systematic review. *Healthcare (Basel)*. 2022;10(4):739.
3. Forbes J, Anatomy JMD. Head and neck, atlantoaxial joint. *StatPearls*. StatPearls Publishing LLC; 2022.
4. González DCN, Ardura Aragón F, Sanjuan JC, et al. C1-C2 rotatory subluxation in adults "a narrative review". *Diagnostics (Basel)*. 2022;12(7):1615.
5. Amat P. Occlusion, orthodontics and posture: are there evidences? The example of scoliosis. *Int J Stomatol Occlusion Med*. 2009;2(1):2-10.
6. Almăşan O, Kui A, Duncea I, Manea A, Buduru S. Temporomandibular joint disk displacements in class II malocclusion and cervical spine alterations: systematic review and report of a hypodivergent case with MRI bone and soft tissue changes. *Life (Basel)*. 2022;12(6):908.
7. Heit T. Neuromuscular orthotics in the treatment of craniomandibular dysfunction and the effects on patients with multiple sclerosis: a pilot study. *Cranio*. 2011;29(1):57-70.
8. Gomes Lde C, Horta KO, Gonçalves JR, Santos-Pinto AD. Systematic review: craniocervical posture and craniofacial smorphology. *Eur J Orthod*. 2014;36(1):55-66.
9. Matheus RA, Ramos-Perez FM, Menezes AV, et al. The relationship between temporomandibular dysfunction and head and cervical posture. *J Appl Oral Sci*. 2009;17(3):204-208.
10. La Touche R, París-Alemany A, von Piekartz H, Mannheimer JS, Fernández-Carnero J, Rocabado M. The influence of cranio-cervical posture on maximal mouth opening and pressure pain threshold in patients with myofascial temporomandibular pain disorders. *Clin J Pain*. 2011;27(1):48-55.
11. D'Attilio M, Epifania E, Ciuffolo F, et al. Cervical lordosis angle measured on lateral cephalograms; findings in skeletal class II female subjects with and without TMD: a cross sectional study. *Cranio*. 2004;22(1):27-44.
12. Bedoya A, Landa Nieto Z, Zuluaga LL, Rocabado M. Morphometry of the cranial base and the cranial-cervical-mandibular system in young patients with type II, division 1 malocclusion, using tomographic cone beam. *Cranio*. 2014;32(3):199-207.
13. Di Giacomo P, Ferrara V, Accivile E, Ferrato G, Polimeni A, Di Paolo C. Relationship between cervical spine and skeletal class II in subjects with and without temporomandibular disorders. *Pain Res Manag*. 2018;2018:4286796.
14. Raya CR, Plaza-Manzano G, Pecos-Martín D, et al. Role of upper cervical spine in temporomandibular disorders. *J Back Musculoskelet Rehabil*. 2017;30(6):1245-1250.
15. Karkazi F, Özdemir F. Temporomandibular disorders: fundamental questions and answers. *Turk J Orthod*. 2020;33(4):246-252.
16. El Hayeck E, Bassil-Nassif N, Khairallah A, El Wak T, Bouserhal J. Effect of head rotation on two-dimensional cephalometric measurements using cone beam–computed tomography. *Clin Oral Investig*. 2023;27(6):2747-2761.
17. Galli M, Papini A, Buffoli B, et al. Assessment of Atlanto-axial and mandibular rotation by cone beam computed tomography. *J Craniofac Surg*. 2018;29(8):2237-2240.
18. Булычева Е, Мамедов АА, Дыбов А, Ищенко Т, Локтионов А. Протокол анализа конусно-лучевой компьютерной томографии у больных с краниомандибулярной дисфункцией. *Стоматология*. 2020;99(6):94-100.
19. Hülse M, Losert-Bruggner B. Temporomandibular joint dysfunction. A consequence of whiplash-injury. *HNO*. 2008;56(11):1114-1121.
20. Flores HF, Ottone NE, Fuentes R. Analysis of the morphometric characteristics of the cervical spine and its association with the development of temporomandibular disorders. *Cranio*. 2017;35(2):79-85.
21. D'Attilio M, Caputi S, Epifania E, Festa F, Tecco S. Evaluation of cervical posture of children in skeletal class I, II, and III. *Cranio*. 2005;23(3):219-228.
22. Saddu SC, Dyasanoor S, Valappila NJ, Ravi BV. The evaluation of head and Craniocervical posture among patients with and without temporomandibular joint disorders- a comparative study. *J Clin Diagn Res*. 2015;9(8):Zc55-Zc58.
23. An JS, Jeon DM, Jung WS, Yang IH, Lim WH, Ahn SJ. Influence of temporomandibular joint disc displacement on craniocervical posture and hyoid bone position. *Am J Orthod Dentofacial Orthop*. 2015;147(1):72-79.
24. Câmara-Souza MB, Figueredo OMC, Maia PRL, Dantas IS, Barbosa GAS. Cervical posture analysis in dental students and its correlation with temporomandibular disorder. *Cranio*. 2018;36(2):85-90.
25. Ekici Ö, Camcı H. Relationship of temporomandibular joint disorders with cervical posture and hyoid bone position. *Cranio*. 2021;18:1-10. doi: 10.1080/08869634.2021.1926745. Epub ahead of print.
26. Michelotti A, Iodice G. The role of orthodontics in temporomandibular disorders. *J Oral Rehabil*. 2010;37(6):411-429.
27. Westersund CD, Scholten J, Turner RJ. Relationship between craniocervical orientation and center of force of occlusion in adults. *Cranio*. 2017;35(5):283-289.
28. Arntsen T, Sonnesen L. Cervical vertebral column morphology related to craniofacial morphology and head posture in preorthodontic children with class II malocclusion and horizontal maxillary overjet. *Am J Orthod Dentofacial Orthop*. 2011;140(1):e1-e7.
29. Serritella E, Impellizzeri A, Musone L, De Stefano AA, Gabriella G. Cranio-cervical posture and rapid palatal expansion therapy. *J Orthod Sci*. 2022;11:13.

How to cite this article: Öztürk K, Danışman H, Akkoca F. The effect of temporomandibular joint dysfunction on the craniocervical mandibular system: A retrospective study. *J Oral Rehabil*. 2023;00:1-7. doi:10.1111/joor.13622

13652842, 0, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/joor.13622 by Dokuz Eylul University, Wiley Online Library on [20/11/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License