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Original Article

Association of temporomandibular joint morphology in patients with and without temporomandibular joint dysfunction: A cone-beam computed tomography based study

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ABSTRACT

Background: The etiology of temporomandibular disorders (TMDs) is complex and associated with multiple predisposing and initiating factors. Articular eminence morphology and steep eminence inclination have been postulated as the etiological factors, but there has been no clear evidence of association of morphology of the temporomandibular joints (TMJ) complex as a probable predisposing factor in the pathogenesis of TMDs.

Materials and Methods: This was a cross-sectional, case–control study, and cone-beam computed tomography scans, and the evaluation was performed for 60 joints in 30 patients with symptomatic TMDs and for 40 healthy joints of 20 age-matched patients. One-way ANOVA, *post hoc*, unpaired *t*-test, Chi-square, and intra-class correlation coefficient test were used to determine the correlation between the TMJ articular eminence inclination, height, condylar bone changes, condyle, and fossa shapes with symptomatic TMDs. The $P < 0.05$ were considered statistically significant.

Results: There was a statistically significant difference of articular eminence inclination and height with a steeper eminence inclination in the control group ($P = 0.044$*, and 0.035*). The condylar bone changes were found to be significantly more in the TMJ disorder group ($P = 0.001$*). There was no significant association of condyle and fossa shapes ($P = 0.482$ and 0.689) and of articular eminence inclination and height with condylar bone changes ($P = 0.695$, 0.498, 0.192, and 0.823) and condyle shapes ($P = 0.389$, 0.521, 0.260, and 0.387). The eminence inclination was not associated with fossa shapes ($P = 0.471$ and 0.086), but eminence height was associated with fossa shapes in the TMJ disorder group ($P = 0.043$* and 0.111).

Conclusion: The results depicted that there was no significant association between TMJ complex anatomy and TMJ disorders in the present study population.

Key Words: Articular eminence inclination, cone-beam computed tomography, eminence height, pneumatized articular eminence, temporomandibular joint, temporomandibular joint disorder

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INTRODUCTION

The temporomandibular joints (TMJ) is a complex articular system which is located between the mandible and the temporal bone.[1] The articular eminence forms the anterior limit of the glenoid fossa[2] and is a part of the temporal bone on which

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the condylar process slides during mandibular movements.[1]

The angle formed by the articular eminence and the Frankfort horizontal (FH) plane or any other horizontal plane, such as the occlusal or palatal plane, is defined as the articular eminence inclination.[3] The articular eminence inclination varies among individuals and dictates the path of condylar movement as well as the degree of rotation of the disc over the condyle. The posterior wall of the articular eminence is an important element in the biomechanics of TMJ and the entire masticatory system. As the steepness of articular eminence increases, the movements of the disc and the condylar process also increases.[4] The steeper the articular eminence the more the condyle is forced to move inferiorly as it shifts anteriorly which results in greater vertical movement of the condyle, mandible, and mandibular arch on opening.[5]

The morphology of the articular eminence, glenoid fossa, and condyle depends on numerous factors. Temporomandibular disorders (TMDs) are frequently associated with degenerative bone changes, which may occur in the subarticular surfaces of the condyle and fossa during TMJ disorders.[6] Erosions appear as pitted and irregular contours of the bony surfaces, and in some instances, the bony surfaces become flattened, and small bone projections may form known as osteophyte.[4]

There are various methods which are used to examine the inclination of the articular eminence and assessment of the morphological changes, but cone-beam computed tomography (CBCT) was used in the present study to assess the TMJ morphology as owing to its higher resolution the visualization of subtle bony changes is much better than conventional techniques. Furthermore, it allows for shorter scanning time and a lower radiation dose than conventional computed tomography (CT).[1,4]

It has been hypothesized that steeper articular eminence is a predisposing factor for TMDs. However, the association of articular eminence inclination and height with TMDs is a matter of controversy and needs to be further evaluated.[7] Furthermore, there has been no clear evidence of association of morphology of TMJ complex as a probable predisposing factor in the pathogenesis of TMDs. Therefore, this study was conducted to evaluate the correlation between the TMJ articular eminence inclination, height, condylar bone changes, condyle, and fossa shapes with symptomatic TMDs using CBCT.

MATERIALS AND METHODS

The study design was a cross-sectional, case–control study. The present study was conducted on patients visiting the Outpatient Department of a reputed dental college of North India after taking the Ethical Clearance from the Institutional Ethical Committee.

The study sample comprised fifty patients within the age range of 20–40 years. The sample was allocated in two groups with thirty patients in Group I (TMJ disorder group) and twenty healthy patients in Group II (Control group). CBCT scans and evaluation was performed for sixty joints in thirty patients with symptomatic TMDs in Group I and for forty healthy joints of 20 age-matched patients in Group II.

Informed consent was taken and the patients were subjected to a detailed case history of the "American Association of Orthodontics" for the analysis of TMDs and thorough clinical examination of the patients was done followed by the recording of findings. All of the patients in the Group I had clinical signs and symptoms of TMJ dysfunction, such as TMJ sounds, clicking, pain, subluxation, trismus, hypomobility, or hypermobility. Any patient with craniofacial abnormalities or any systemic conditions that may affect the TMJ, patients with a history of trauma to orofacial complex, under any systemic corticosteroids, undergoing orthodontic appliance therapy or any intervention from other previous TMJ treatment, scans with artifacts, and pregnant females were excluded from the study. The patients for control group were selected from CBCT scans, which were performed for reasons other than TMJ dysfunction. The assessment was made by three oral and maxillofacial radiologists at an interval of 2 weeks with a minimum experience of 5 years in CBCT interpretation who were blinded to eliminate the inter-observer and intra-observer bias.

Imaging procedure

The CBCT images were taken with a NewTom GiANO (CEFLA-SC, CEFLA DENTAL GROUP, ITALY) with a maximum output of 90 kvp, 3 mAs, and typical exposure time of 3.6 s, voxel resolution of 150 μ and the field of view (FOV) of 8 cm × 8 cm. The patients were made to stand in the gantry with head in the horizontal position and hence that the FH plane was perpendicular to the table.

All the CBCT scans were taken using a standard exposure and patient positioning protocol to ensure standardization. Two scout images, i.e., sagittal and coronal view were taken in accordance with the patient's position and a 360° scan was acquired afterward. The NNT software version 7.0 program (New Net Technologies Ltd. Naples, USA) was used for the analysis. The orientation and area of interest were determined in Multiplanar reformation (MPR) format. First, the condylar head was oriented and triangulated in all the three planes. Then, in axial window, the widest mesiodistal dimension of the condyle was identified which acted as the reference point for secondary reconstruction. On this plane, parasagittal and para-coronal cross-sections were created. The parasagittal sections were evaluated perpendicular to the long axis of the condyle and para-coronal cross-sections were created parallel to the long axis of condyle with slice thickness and interval of 1 mm each, respectively.

Measurements

The points used for measurements of the articular eminence inclination and heights in this study are as follows [Figure 1]:

- For each patient, the mid parasagittal section was taken up for measurement of the articular eminence inclination and height
- On the designated section, two points were localized; superior most point on the porion (P) and the inferior most point of the articular eminence (E). Then, a straight line joining these two points was drawn using the drawing toolbar
- Then, the highest point of the articular fossa (R) was marked and another line was drawn intersecting the other line joining the point (R) to the inferior most point of the articular eminence (E)
- The angle at this intersection depicted the articular eminence inclination and was measured using the angle toolbar of the software
- The eminence height was established by measurement of the perpendicular distance between the lowest point of the articular eminence and the highest point of the fossa.

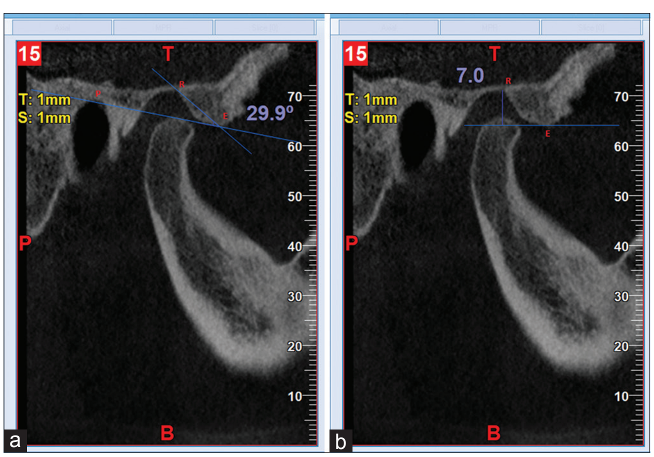

Figure 1: articular eminence (a) inclination (b) height.

The condylar bone changes were evaluated and categorized as normal, erosion, and osteophyte formation as visualized in the coronal plane [Figure 2]. The basic shapes used for classification were triangular, oval, flattened, and round for the condyles in a coronal plane [Figure 3] and triangular, trapezoidal, oval, and round for the fossa in the sagittal plane [Figure 4].[2] We used the central coronal slice to determine the condyle shape and the central sagittal slice to determine the fossa shape. The same procedure was followed for all scans.

Statistical analysis

The software used for the statistical analysis was Statistical Package for the Social Sciences (SPSS) software (version 21.0. Armonk, NY: IBM Corp). One-way ANOVA test was used to compare the mean articular eminence inclination and height according to condylar bone changes, condyle shapes, and fossa shapes. *Post hoc* test was applied to compare the intergroup comparison of mean inclination and height according to condylar bone changes, condyle shapes, and fossa shapes. Unpaired or independent *t*-test was used to compare the mean articular eminence inclination and height in both the groups. A Chi-square test was used to compare the distribution of condylar bone changes, condyle shapes, and fossa shapes in both groups. Intra-class correlation coefficient test was used to evaluate the intra-observer and inter-observer variation. The $P < 0.05$ were considered statistically significant.

RESULTS

The comparison of the distribution of condylar bone changes was compared between TMJ disorder and control groups [Table 1] using the Chi-square test. The incidence of erosion and osteophyte was more in the TMJ disorder group and the difference was statistically significant ($P = 0.001$). The distribution of condyle and fossa shapes was compared between the two groups using the Chi-square test [Table 1] and there

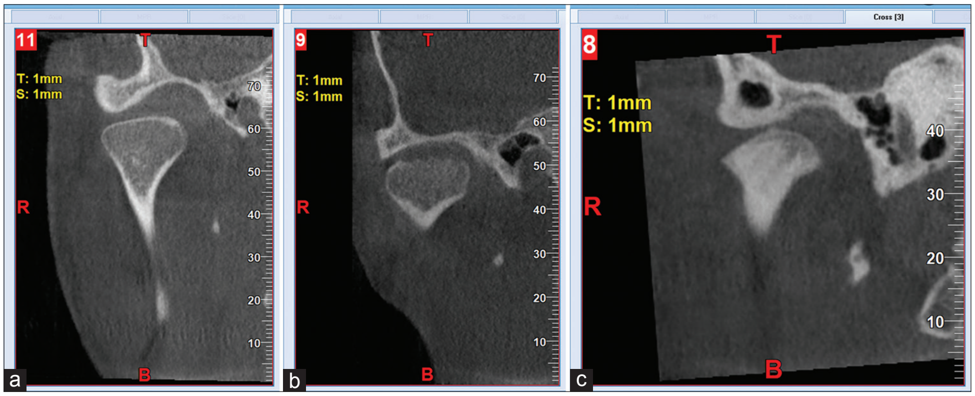

Figure 2: Condylar bone changes in a coronal view: (a) normal (b) erosion (c) osteophyte.

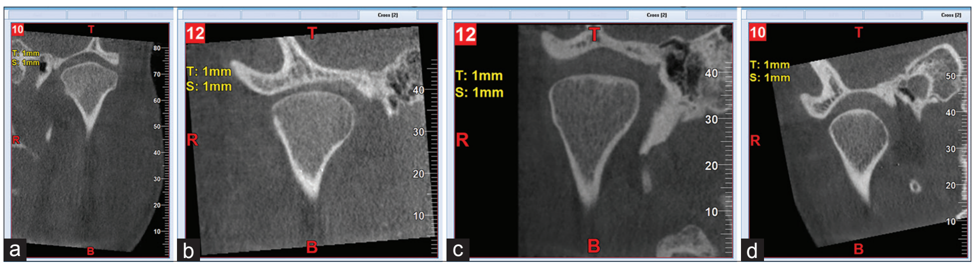

Figure 3: Condyle shapes in a coronal view: (a) triangular (b) oval (c) flattened (d) round.

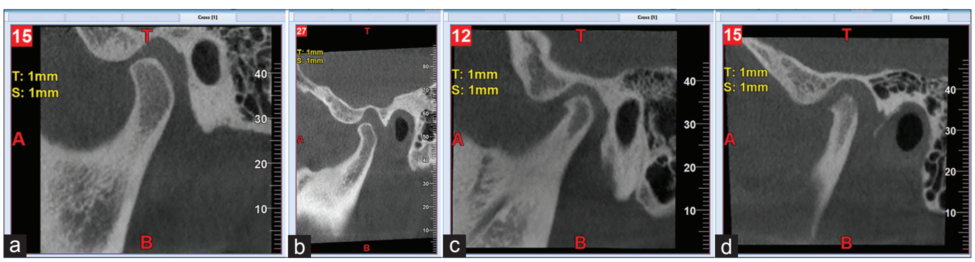

Figure 4: Fossa shapes in a sagittal view: (a) triangular (b) oval (c) trapezoidal (d) round.

Table 1: Distributions of the condylar bone changes, condyle shapes, and fossa shapes in the temporomandibular joint disorder and control group

Morphological variations	Total (*n*)	TMJ disorder group (%)	Control group (%)	χ^2	*P*
Condylar bone changes					
Normal	71	32 (53.3)	39 (97.5)	23.983	0.001*
Osteophyte	3	2 (3.3)	1 (2.5)		
Erosion	26	26 (43.3)	0		
Condyle shape					
Triangular	35	24 (40.0)	11 (27.5)	2.462	0.482
Oval	29	15 (25.0)	14 (35.5)		
Flattened	24	13 (21.7)	11 (27.5)		
Round	12	8 (13.3)	4 (10.0)		
Fossa shape					
Triangular	30	20 (33.3)	10 (25.9)	1.469	0.689
Oval	41	23 (38.3)	18 (45.0)		
Trapezoidal	7	5 (8.3)	2 (5.0)		
Round	22	12 (20.0)	10 (25.0)		

*P<0.05, using Chi-square test. TMJ: Temporomandibular joint

was no statistically significant difference (P = 0.482, P = 0.689, respectively).

The articular eminence inclination and height were compared in both the groups using unpaired or independent *t*-test [Table 2]. There was a statistically significant difference of articular eminence inclination (P = 0.044) and height (P = 0.035) between the TMJ disorder and control group. The articular eminence inclination was more in control group, whereas the articular eminence height was more in the TMJ disorder group.

The association of articular eminence inclination and height with condylar bone changes, condyle shapes, and fossa shapes was evaluated using one-way anova [Tables 3 and 4]. There was no significant association of articular eminence inclination and height with condylar bone changes and condyle shapes in both the groups. The articular eminence inclination was not associated with fossa shapes in both the groups and articular eminence height was associated with fossa shapes only in the TMJ disorder group.

Interclass correlation coefficient for inter-observer reliability varied from 0.953 to 0.990 and for intraobserver reliability varied from 0.927 to 0.987, which suggested excellent agreement.

Table 2: Differences in the eminence inclination and height values in the temporomandibular joint disorder and control groups

Articular eminence morphology	TMJ disorder group		Control group		*P*
	n	Mean±SD	*n*	Mean±SD	
Inclination	60	32.23°±7.68°	40	34.97°±7.69°	0.044*
Height (mm)	60	6.30±1.61	40	5.66±1.23	0.035*

*P<0.05, using unpaired test. SD: Standard deviation; TMJ: Temporomandibular joint

DISCUSSION

TMDs are the major cause of nonodontogenic pain in the oral and maxillofacial region and include various groups of disorders, which include psychological, masticatory, and muscular components with overlapping features.[8]

The etiology of TMDs is complex and multifactorial,[9] and in spite of multitudinous research activities, the etiology of TMDs is still an enigma.[10] Because of varied and unexplainable etiology, the management of TMDs patients is a particular challenge. The key to successful management is the diagnosis of all predisposing, initiating, and perpetuating factors.[10] Since alterations in the articular eminence morphology have been stated as an etiological factor for TMDs,[7,11] we tried to explore the association between articular eminence morphology and TMDs.

The articular eminence is situated in front of the glenoid fossa and its posterior surface slope varies among people. Although it is an anatomical structure belonging to the cranium, its morphological shape is mainly influenced when it is exposed to functional load arising from chewing forces.[1] The normal value of the articular eminence in adults has been reported to be 30°–60°. If the articular eminences inclination is <30° it is characterized as flat, whereas if the value is >60° it is characterized as steep.[3]

Articular Eminence Inclination is studied using different materials and methods as it is an important element in the biomechanics of TMJ.[12] The various methods include measurements on models taken from

Table 3: Eminence inclination and height values according to the condylar bone changes, condyle shape, fossa shape in the temporomandibular joint disorder group

Morphological variations	*n*	Eminence inclination	*P*	Height (mm)	*P*
Condylar bone changes					
Normal	32	33.03°±6.34°	0.695	5.95±1.54	0.192
Erosion	2	31.48°±5.83°		6.23±0.99	
Osteophyte	26	31.30°±9.29°		6.73±1.67	
Condyle shape					
Triangular	24	33.82°±8.20°	0.389	6.21±1.36	0.260
Oval	15	32.79°±7.82°		6.18±1.32	
Flattened	13	29.41°±4.94°		5.97±1.94	
Round	8	30.99°±9.33°		7.34±2.08	
Fossa shape					
Triangular	20	30.25°±7.84°	0.471	5.73±1.89	0.043*
Oval	23	33.65°±6.83°		6.75±1.37	
Trapezoidal	5	30.74°±12.30°		5.21±1.86	
Round	12	33.41°±6.96°		6.84±0.95	

*P<0.05, using One-way ANOVA

Table 4: Eminence inclination and height values according to the condylar bone changes, condyle shape, fossa shape in control group

Morphological variations	n	Eminence inclination	P	Height (mm)	P
Condylar bone changes					
Normal	39	34.84°±7.74°	0.498	5.65±1.25	0.823
Osteophyte	1	40.20°		5.93	
Condyle shape					
Triangular	11	35.55°±9.05°	0.521	5.36±1.20	0.387
Oval	14	32.82°±8.85°		5.41±1.07	
Flattened	11	35.66°±5.59°		6.13±1.43	
Round	4	38.99°±2.52°		6.00±1.28	
Fossa shape					
Triangular	10	29.72°±9.86°	0.086	5.64±0.98	0.111
Oval	18	36.68°±6.94°		6.10±1.26	
Trapezoidal	2	39.19°±6.49°		4.72±0.73	
Round	10	36.29°±4.60°		5.05±1.25	

*$P<0.05$, using One-way ANOVA[4]

an impression of the fossa or direct measurement carried out on dry skulls, measurements taken by interocclusal protrusive records, measurements performed on arthrograms, panoramic radiographs, tomographic radiographs,[3] cephalometric radiographs, and scaled photographs. The articular eminence and glenoid fossa have a complicated structure due to many small and complex curved surfaces that make these measurements difficult.[3,12]

It has been demonstrated that CBCT is an appropriate method for the measurements of the articular eminence and offers a dose and cost-effective alternative to conventional CT for the diagnostic evaluation of osseous abnormalities of the TMJ. The effective dose of the currently available large FOV CBCT units is higher than that of conventional panoramic imaging but several to many times lower than the reported doses for conventional CT. CBCT also allows linear measurements with real dimensions and without superimposition or distortion, which is the main concern in conventional radiography.[1] It provides sub-millimeter spatial resolution images because of which minute details can be observed with markedly shorter scanning times (10–70 s).[13] Therefore, CBCT was used in this study to determine the articular eminence inclination and height, condylar bone changes, fossa, and condyle shapes in patients. In the present study, the central sagittal slice of the condyle for measurements was chosen as the view of the eminence in the central slice reflects the steepest part of the eminence and gives the best representation of the eminence inclination.[1] The major growth of the articular eminence inclination is completed by the age of 20 years[7], and as the age advances, there are more chances of osteoarthritic changes which can affect the morphology of the TMJ. Therefore, participants <20 years and >40 years of age were excluded from this study.

A pronounced steepness of the articular eminence has been suggested as a predisposing factor in the development of the TMJ disorders as with a steep articular eminence, the disk would have to rotate forward on the condyle to maintain a proper condyle-disk relationship during mandibular movements.[14] Meanwhile, the masseter and temporalis produce a stabilizing force, which with a steeper eminence, places a greater relative distalizing force relative to the disc which might result in laxity of the ligaments that attach the disc to the condyle.[11] As a consequence, during mouth opening, the disk articulating against a steep eminence would achieve a gradually increasing anterior position in relation to the condyle, predisposing the disk to anterior displacement. This has been stated as the biomechanical theory of the TMJ anterior disk displacement.[14]

Apart from the articular eminence inclination, TMJ morphology is also related to TMDs. Richards[15] has stated that the morphology of the TMJ is related to the morphology of the system with which the joint is functionally linked which includes environmental and oro-functional factors such as mechanical loading, genetic factors, para-functional habits that may influence the growth and development of skeletal components of the TMJ. The patterns of forces generated during the mastication lead to the remodeling of the glenoid fossa, and with stronger forces, the fossa becomes deeper, whereas the AEI becomes steeper.[12,16]

In the present study, the articular eminence inclination was greater in the control group (34.97 ± 7.69) than in patients with TMJ dysfunction (32.23 ± 7.68), and the difference were statistically significant. These results were in accordance with Sümbüllü *et al*.[1] and Ren *et al*.[17] On the contrary, Gökalp *et al*.[18] and Sülün *et al*.[19] reported that a greater articular eminence inclination in patients with TMJ disorders. The differences may be attributed to the varied and wide age range of patients included in their study.

The articular eminence height was more in the TMJ disorder group (6.30 ± 1.61) in comparison to the control group (5.66 ± 1.23), and the difference was statistically significant. Similar results were reported by Paknahad *et al*.[7] In a study by Caglayan *et al*.[4] eminence height was more in the TMJ disorder group, but the difference was not statistically significant.

We evaluated morphological changes and observed condylar bone changes in only 28 (46.6%) of sixty joints in the TMJ disorder group, and in the control group, we observed only 1 (2.5%) joint of forty joints with condylar osteophyte formation. A significant difference was found between condylar bone changes in two groups as the occurrence of erosion and osteophyte was significantly more among the TMJ disorder group. Similarly, dos Anjos Pontual *et al*.[6] and Koyama *et al*.[13] found the prevalence of bone changes in 71% and 63.7% of the joints of patients with TMDs using CT. However, in the study of Capurso *et al*.,[20] degenerative bone changes were seen only in 19.6% of the 461 patients.

Osteophytes occur at an advanced stage of degenerative change and appear to stabilize and widen the surface in an attempt to improve the overload resulting from occlusal forces, representing areas of neo-formed cartilage, whereas erosion is the initial stage of degenerative changes, indicating that the TMJ is unstable and changes in bone surfaces will occur, probably resulting in changes in occlusion.[6] According to Alexiou *et al*.,[21] patients in older age groups are expected to have more frequent and severe bone changes than those in younger age groups. The degenerative changes are the long-term consequences of TMJ disorders, but sometimes, they can be detected incidentally on radiographs.[13]

There was no significant difference of condyle and fossa shape between the TMJ disorder and control group. The triangular condyle shape was observed more frequently, i.e., in 24 (40%) joints in the TMJ disorder group and oval condyle shape was observed in 14 (35%) joints in the control group. Oval fossa shape was found most frequently in both the groups (41%). Our results were not in accordance with Caglayan *et al*.[4] as they reported significant differences between the condyle and fossa shapes in the TMJ disorder and control groups.

Pirttiniemi *et al*.[22] affirmed a strong functional dependence between the articular eminence and the condyle. According to Wang *et al*.,[23] the initial development of the glenoid fossa is independent of the condyle, but its continuous development relies on an interaction with the condyle. If the interaction of the glenoid fossa and the condyle interferes with the growth pattern of these structures, then it also interferes with its morphology and is unique for each patient.[24]

Association of the articular eminence inclination and height with condyle and fossa morphology was also assessed and there was no association with the condylar bone changes and condyle shapes. Our results were in accordance with Caglayan *et al*.[4] as they also found no significant association of the articular eminence inclination and height with condylar bone changes. However, they found a significant association of the articular eminence inclination and height with condyle shapes only in the control group.

In our study, we did not find any association of the articular eminence inclination with fossa shapes in both the groups. However, there was a significant association of the articular eminence height with fossa shapes in the TMJ disorder group. Our results were not in accordance to Caglayan *et al*.,[4] as they found a significant association of the articular eminence inclination with fossa shapes in both the TMJ disorder and control group, whereas articular eminence height was only associated with fossa shapes in control group. Katsavrias and Halazonetis[25] stated that the variability of the fossa shape and condyle shape was related to the eminence inclination and condylar inclination, respectively.

The reason for the variations in the results could be due to factors such as different methods of measurements, sample size, age range, and other differences between the populations. Further studies are required with a larger sample size to determine an association between TMJ complex anatomy and etiopathogenesis of specific TMD.

CONCLUSION

The present study shed light on the relationship between TMJ morphology and the incidence of TMDs. The articular eminence inclination was steeper in patients without TMJ dysfunction and thus, the steep articular eminence inclination could not be considered as a predisposing factor in etiology of TMDs in the present study population. There was increased articular eminence height in the TMJ disorder group, and it can be proposed that increased articular eminence height might be a predisposing factor in the etiology of TMDs. The condylar bone changes had an association with TMJ disorders in the present study population, and there was no association of articular eminence inclination and height with the condylar bone changes and condyle shapes. Furthermore, the articular eminence inclination had no association with fossa shapes, but eminence height was associated with fossa shapes only in the TMJ disorder group. Thus, the results depicted that there was no significant association between TMJ complex anatomy and TMJ disorders.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

REFERENCES

1. Sümbüllü MA, Cağlayan F, Akgül HM, Yilmaz AB. Radiological examination of the articular eminence morphology using cone beam CT. Dentomaxillofac Radiol 2012;41:234-40.
2. İlgüy D, İlgüy M, Fişekçioğlu E, Dölekoğlu S, Ersan N. Articular eminence inclination, height, and condyle morphology on cone beam computed tomography. Scientific World Journal 2014;1-6.
3. Katsavrias EG. Changes in articular eminence inclination during the craniofacial growth period. Angle Orthod 2002;72:258-64.
4. Caglayan F, Sumbullu M, Akgul H. Associations between the articular eminence inclination and condylar bone changes condylar movements and condyle and fossa shapes. Oral Radiol 2014;30:84-91.
5. Venancio Rde A, Camparis CM, Lizarelli Rde F. Low intensity laser therapy in the treatment of temporomandibular disorders: A double-blind study. J Oral Rehabil 2005;32:800-7.
6. dos Anjos Pontual ML, Freire JS, Barbosa JM, Frazão MA, dos Anjos Pontual A. Evaluation of bone changes in the temporomandibular joint using cone beam CT. Dentomaxillofac Radiol 2012;41:24-9.
7. Paknahad M, Shahidi S, Akhlaghian M, Abolvardi M. Is mandibular fossa morphology and articular eminence inclination associated with temporomandibular dysfunction? J Dent (Shiraz) 2016;17:134-41.
8. Maia ML, Bonjardim LR, Quintans Jde S, Ribeiro MA, Maia LG, Conti PC. Effect of low-level laser therapy on pain levels in patients with temporomandibular disorders: A systematic review. J Appl Oral Sci 2012;20:594-602.
9. Okeson JP. Management of Temporomandibular Disorders and Occlusion. 6th ed. St Louis (MO): The CV Mosby Company; 2008.
10. Singla S, Bida L, Rehan S. Comprehensive review of temporomandibular joint disorder management. IJRID 2016;6:1-7.
11. Ozkan A, Altug H, Sencimen M, Senel B. Evaluation of articular eminence morphology and inclination in TMJ internal derangement patients with MRI. Int J Morphol 2012;30:740-4.
12. Kranjčić J, Šlaus M, Vodanović M, Peršić S, Vojvodić D. Articular eminence inclination in medieval and contemporary croatian population. Acta Clin Croat 2016;55:529-34.
13. Koyama J, Nishiyama H, Hayashi T. Follow-up study of condylar bony changes using helical computed tomography in patients with temporomandibular disorder. Dentomaxillofac Radiol 2007;36:472-7.
14. Isberg A, Westesson PL. Steepness of articular eminence and movement of the condyle and disk in asymptomatic temporomandibular joints. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;86:152-7.
15. Richards LC. Temporomandibular joint morphology in two Australian aboriginal populations. J Dent Res 1987;66:1602-7.
16. Imanimoghaddam M, Madani AS, Mahdavi P, Bagherpour A, Darijani M, Ebrahimnejad H. Evaluation of condylar positions in patients with temporomandibular disorders: A cone-beam computed tomographic study. Imaging Sci Dent 2016;46:127-31.
17. Ren YF, Isberg A, Westesson PL. Steepness of the articular eminence in the temporomandibular joint. Tomographic comparison between asymptomatic volunteers with normal disk position and patients with disk displacement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;80:258-66.
18. Gökalp H, Türkkahraman H, Bzeizi N. Correlation between eminence steepness and condyle disc movements in temporomandibular joints with internal derangements on magnetic resonance imaging. Eur J Orthod 2001;23:579-84.
19. Sülün T, Cemgil T, Duc JM, Rammelsberg P, Jäger L, Gernet W. Morphology of the mandibular fossa and inclination of the articular eminence in patients with internal derangement and in symptom-free volunteers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:98-107.
20. Capurso U, Scutellari PN, Orzincolo C. Involvement of the temporomandibular joint in the rheumatoid arthritis. Radiol Med 1996;78:299-4.
21. Alexiou K, Stamatakis H, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. Dentomaxillofac Radiol 2009;38:141-7.

22. Pirttiniemi P, Kantomaa T, Rönning O. Relation of the glenoid fossa to craniofacial morphology, studied on dry human skulls. Acta Odontol Scand 1990;48:359-64.
23. Wang Y, Liu C, Rohr J, Liu H, He F, Yu J, *et al*. Tissue interaction is required for glenoid fossa development during temporomandibular joint formation. Dev Dyn 2011;240:2466-73.
24. Rabelo KA, Sousa Melo SL, Torres MGG, Campos PSF, Bento PM, Melo DP. Condyle Excursion Angle, Articular Eminence Inclination, and Temporomandibular Joint Morphologic Relations With Disc Displacement. J Oral Maxillofac Surg. 2017;75(5):938.
25. Katsavrias EG, Halazonetis DJ. Condyle and fossa shape in Class II and Class III skeletal patterns: A morphometric tomographic study. Am J Orthod Dentofacial Orthop 2005;128:337-46.