



Evaluation of styloid chain calcification related to temporomandibular joint disc displacement: a retrospective cohort study

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Abstract

Objectives The present study aimed to evaluate any relationship between elongated styloid process (ESP) and temporomandibular joint disc displacement (TMJD). Study design: A retrospective cohort study. Setting: Dentomaxillofacial Radiology division of Erciyes University Dental Hospital. Participants: Ninety-four temporomandibular joints (TMJs) of 47 patients were allocated in this study. Intervention-disease: Two experienced dentomaxillofacial radiologists have interpreted all CBCT and MR images. Patients who referred with TMJ disorders were classified according to temporomandibular joint's disc status as normal disc position (ND), displacement with reduction (DWR) and displacement without reduction (DWRoR).

Methods Main outcome measures: Interpretation of styloid chain calcification pattern and styloid processes length measured linearly on reconstructed sagittal slices of CBCT. Randomization: Cone beam computed tomography (CBCT) and magnetic resonance (MR) images of 154 patients who were admitted between September 1, 2012 and September 1, 2019. Only 47 of them fulfilled the study requirements. Blinding: Single blind of the outcome measurements and interpretations of MR images.

Results Total 94 TMJs of 47 patients disc status groups were analyzed and defined as DWRoR ($n = 25$), DWR ($n = 32$), and ND ($n = 37$). On multivariate analysis, no statistical significant differences were found between groups in terms of styloid process lengths. Mean SP length and standard deviation of disc status groups (DWRoR, DWR, and ND) are $35.5 (\pm 9.8)$ mm, $34.6 (\pm 9.2)$ mm, and $38.3 (\pm 8.9)$ mm, respectively. When patients were grouped individually according to their post-MRI diagnosis, the mean styloid process length in the non-temporomandibular joint disc displacement (non-TMJD) patients (47.9 ± 10.8) was significantly higher than the TMJD patients (36.1 ± 9.3). In this study, there is no intervention to cause any harm or side effects.

Conclusion Our results indicate that styloid-stylohyoid syndrome may be misdiagnosed with temporomandibular joint disorder (TMD).

Trial registration Clinical Trials NCT04280107.

Keywords Temporomandibular joint disorder · Elongated styloid process · Magnetic resonance imaging · Cone beam computed tomography

Introduction

The styloid process (SP) of the temporal bone is a long conical cartilaginous projection that lies anterior to the mastoid process. The SP is located in the anterior lateropharyngeal

space, between the external carotid artery, palatine tonsil, styloglossus, and stylopharyngeal muscles. The stylohyoid chain is composed of the SP, the stylohyoid ligament and the cornu minus of the hyoid bone [1]. Embryologically, the stylohyoid chain originates from the second branchial arch (Reichert's cartilage) [2]. The normal length of the SP on dental panoramic radiographs (DPRs) was reported as between 20–30 mm [3]. Previous studies reported that while measuring the length of the SP, no significant difference was found between the DPRs and cone beam computed tomography (CBCT) [4, 5]. Although the etiology of the styloid chain calcification or elongation of the styloid process (ESP) is unclear, some authors claimed that the increased tensile

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stress in the stylohyoid ligament might be responsible for this clinical condition [6]. Patients who have ESP or styloid chain calcification are usually asymptomatic; only 4% of the patients with ESP in this study were. Symptoms may vary depending on the affected anatomic structures by calcified process or ligament. Classic Eagle syndrome, carotid artery syndrome, stylohyoid syndrome, and pseudostylohyoid syndrome are the most common entities [7–9].

Temporomandibular joint disc displacement (TMJD) was described as the abnormal relationship of the articular disc with articular eminence and condyle. It is the most common form of TMJ disorders. Although there are widely used clinical examinations to diagnose TMJD, magnetic resonance imaging is accepted as the gold standard to identify TMJD [10].

Previous studies stated that the orofacial pain related to TMJ disorders and the orofacial pain related to ESP or styloid chain calcification have similar features. It is possible to misdiagnose these above-mentioned clinical conditions. Therefore, the possible relationship between ESP or styloid chain calcification and TMJ disorders has been studied in the literature. In previous studies, any association between stylohyoid chain calcification and temporomandibular disorders was investigated [4, 11–19]. However, the previous studies did not investigate the relationship between ESP and TMJD as a specific subgroup. Also, the diagnoses of TMJ disorders were based on solely clinical examinations.

The aim of this study is to investigate the relationship between the styloid process calcification and TMJD. In addition, the length and calcification pattern of the styloid process were also evaluated according to various TMJ disc positions.

Materials and methods

Sample collection

The present study was approved by the local ethics committee (Ref no: 2018/615). One hundred and fifty-four patients who were admitted to Department of Oral and Maxillofacial Radiology with TMJ complaints between 2013 and 2019 were included in the presented retrospective study.

Patients who were diagnosed with TMJ disorders and had an MRI and CBCT record of the same month were included in the study. The exclusion criteria were defined as previous surgical operations in the TMJ region, previous or current orthodontic treatment, trauma and rheumatic diseases.

The sample size was not calculated, and all remaining 47 patients were included in the study because the patient data obtained after the inclusion and exclusion criteria were applied were limited. All participants provided informed consent. The study was planned as split-mouth and

analyses and measurements were performed on 94 joints of 47 patients. There was no control group in the study. The styloid process length obtained was interpreted according to the reference values in the literature.

MR interpretation and CBCT measurement

MR imaging was performed on a 1.5 T scanner (Gyrosan Intera, Philips Medical Systems, The Netherlands) with head sense coil. In the oblique sagittal plane, T1-weighted turbo spin-echo (TSE) images [repetition time ms/echo time ms 550/10; slice thickness 2.5 mm; field of view (FOV), 180 mm; matrix 256 × 204], T2-weighted TSE images (3000/120, slice thickness 2.5 mm, FOV 180 mm, matrix 256 × 170); in the oblique coronal plane, T1-weighted three-dimensional (3D) fast field echo (FFE) images (25/4.6, slice thickness 2 mm; FOV 189.9 mm; matrix 256 × 170) were obtained in the closed-mouth position. In the oblique sagittal plane, T2 FFE Dynamic (MOVIE) (226/14, 3 mm, 160 mm, 240 × 192) was obtained in the closed, semi-open, and open-mouth position. The TMJ disc position was evaluated on MRI scans. MRI scans were interpreted on sagittal sections according to the following three classifications: normal disc position (ND) (Fig. 1), disc displacement with reduction (DWR) (Fig. 2), and disc displacement without reduction (DWR) (Fig. 3) [20].

For the classification of disc position, the criteria were used as suggested by Ahmad et al. [21].

- Normal disc position (ND): in the sagittal plane, the disk position in a closed-mouth position was considered normal if the thickest part of the posterior band was located at the top of the condyle at 11:30–12:30 o'clock position.
- Disc displacement with reduction (DWR): in the sagittal plane, in a closed-mouth position, if the thickest part of the posterior band is seated anterior to the 11:30 o'clock position, it is defined as anterior disc displacement. The intermediate zone of the disc is seated anterior to the condyle. In open-mouth position, the articular disc returns to its normal position.
- Disc displacement without reduction (DWR): in the sagittal plane, in a closed-mouth position, the articular disc is observed as anteriorly displaced. In open-mouth position, the displaced disc does not reduce to its normal position.

According to the diagnoses made with MRI interpretations, patients were divided into two groups. Patients who had at least one joint disc displacement called TMJD patients and patients without disc displacement in both joints called non-temporomandibular joint disc displacement (non-TMJD) patients.

Fig. 1 TMJ with normal disc position in magnetic resonance images. **a** In closed mouth position in T1-weighted image; the posterior border of the articular disc at 12 o'clock. **b** In the dynamic image, the articular disc is observed between the condyle and the articular eminence in the open mouth position (thin arrow: articular disc, thick arrow: glenoid fossa, c: condyle)

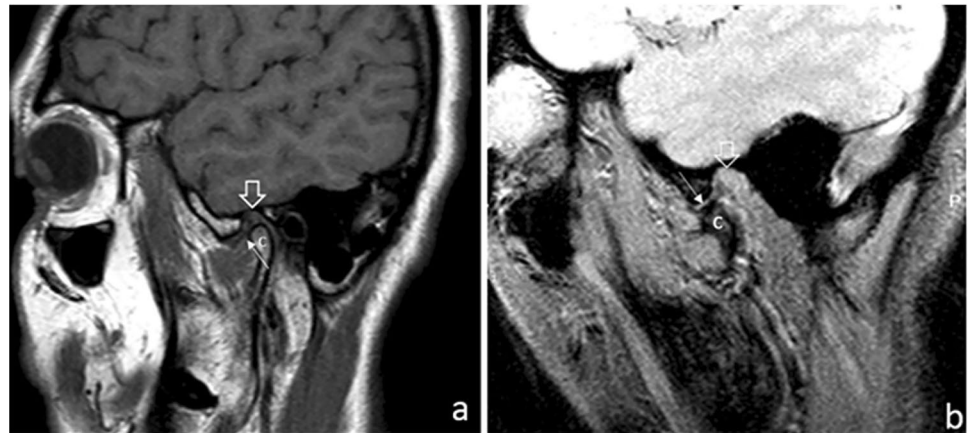


Fig. 2 TMJ with reduction disc displacement in magnetic resonance images. **a** Closed mouth position in T1-weighted image; the articular disc indicated by the white arrow is in the anterior position. **b** In the dynamic image, the disc indicated by the white arrow in the open mouth position is observed in its normal position

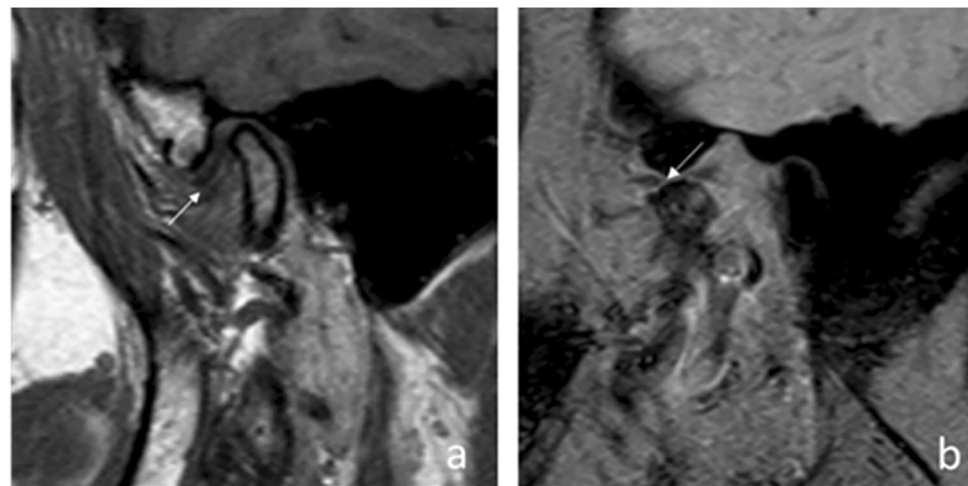
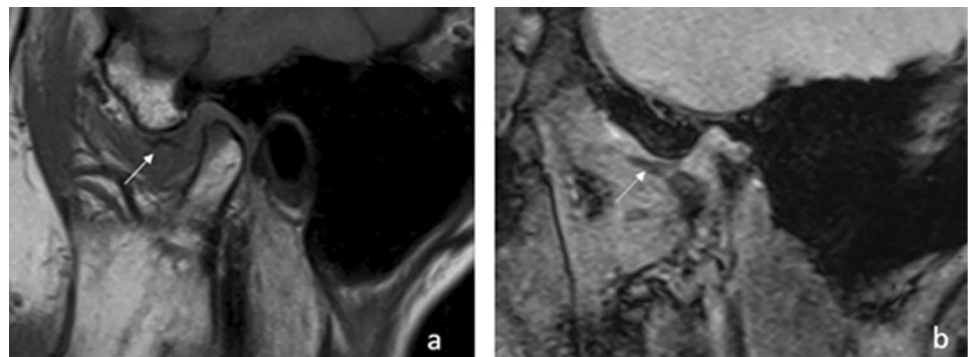


Fig. 3 TMJ without reduction disc displacement in magnetic resonance images. **a** Disc in the anterior position indicated by the white arrow in the closed mouth position in the T1-weighted image. **b** Disc maintaining the anterior position indicated by the white arrow in the open mouth position in the dynamic image



CBCT images were used to measure the length of the styloid process. All CBCT images were obtained using a NewTom 5G CBCT machine (QR, Verona, Italy) at 110 kV and 3–5 mA, 0.16-mm voxel size, and 5.4 s exposure time. The CBCT images were analyzed with NNT software on a 32-inch Dell LCD screen (Dell, Round Rock, TX) with a resolution of 1280 × 1024 pixels in a darkroom. While making CBCT measurements, measurements were

made on sagittal sections passing through the long axis of the styloid process adjusted according to the coronal section. The endpoint of the last observation of the calcified part continuing along the styloid ligament pathway extending from the styloid process on the same section was accepted as the endpoint (Fig. 4). While measuring segmented-type ligament calcification, the cleft between the temporal bone's tympanic plate and the SP was accepted

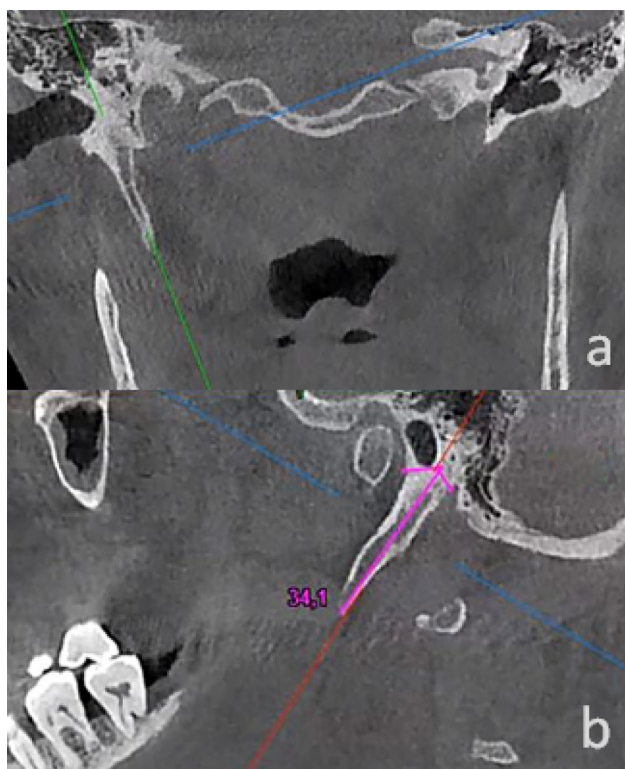


Fig. 4 Shows a representative image of a CBCT measurement. **a** The best viewing sagittal plane adjusted according to the coronal section. **b** Measurements were made on sagittal sections passing through the long axis of the styloid process

as the origin. The entire length origin from this point and continuing along the ligament to the last point where the calcified part was observed was linearly measured and recorded as SP length. According to the elongated styloid process classification of Langlais et al. [22], the styloid process type was also evaluated as follows:

- **Elongated:** The mineralized stylohyoid ligament is observed as the uninterrupted integrity with the styloid process.
- **Pseudoarticulated:** The styloid process is apparently joined to the mineralized stylohyoid ligament by a single pseudoarticulation.
- **Segmented:** This type consists of either short or long non-continuous or interrupted segments of the mineralized ligament.

CBCTs and MRIs belonging to the patients obtained from the archive were recorded as numerical numbers to avoid any bias in the measurements. All CBCT images were evaluated by one dentomaxillofacial radiologist (HCK) and all MR Images were evaluated by a second dentomaxillofacial radiologist (DSC). While taking measurements, observer one (HCK) did not know the MRI diagnosis of the joints.

Statistic analysis

Descriptive statistics were conducted. Shapiro–Wilk analysis was used to test the normality of data. To determine the homogeneity of variances, Levene test was applied. To multiple comparisons and post hoc analysis, one-way ANOVA and Tukey HSD were applied, respectively. Pearson’s Chi squared test was used to compare categorical variables. Any styloid process length differences between sex groups were analyzed by an independent sample *t* test. Power analyses were performed after the one-way ANOVA, Tukey HSD and independent sample *t*-test to determine the effect sizes. All statistical analyses were performed using R Statistical Software (Foundation for Statistical Computing, Vienna, Austria) [23]. The significance level was set at 5%.

Results

A total of 47 patients, 3 males, and 44 females were included in the study. Gender and age distributions of the study patients are given in Table 1. Gender–age distributions according to the disc status and the SP status of the study patients are given in Tables 2 and 3, respectively. According to the Pearson’s Chi squared test, there was no statistically significant relationship found between the mean disc status and the mean SP status ($p=0.757$). The distribution of the disc status by SP status is shown in Table 4. Disc status groups did not differ significantly with respect to mean styloid process lengths ($p=0.101$). Table 5 shows the mean styloid process length according to the disc status groups, the results of the ANOVA test and the Power analysis. Also,

Table 1 Patients demographic characteristics

Sex	Number of patients	Mean age (SD)
Male	3	34.3 (11.1)
Female	44	42.6 (17.1)
Total	47	42.1 (16.8)

Table 2 Patients demographic characteristics by the disc status groups

Disc Status	Sex	<i>n</i> ^a (%)	Age (mean ± SD)
Normal disc position	Male	5 (5.3)	32.8 ± 11.7
	Female	32 (34)	43.6 ± 17.8
Displace with reduction	Male	0	–
	Female	32 (34)	45.2 ± 16.7
Displace without reduction	Male	1 (1.1)	42
	Female	24 (25.5)	37.9 ± 16.2

^aNumber of temporomandibular joint

Table 3 Patients demographic characteristics by the SP status groups

Styloid process status	Sex	n ^a (%)	Age (mean ± SD)
Elongated	Male	3 (3.2)	34. ± 12.7
	Female	60 (63.8)	44.6 ± 16.6
Pseudoarticulated	Male	0	–
	Female	3 (3.2)	43.7 ± 23.5
Segmented	Male	3 (3.2)	34 ± 12
	Female	25 (26.6)	37.7 ± 17

^aNumber of temporomandibular joint

Table 4 The distribution of the disc status by SP status

	ND (%)	DWoR (%)	DWR (%)
Elongated	24 (64.86)	16 (64.00)	23 (71.88)
Pseudoarticulated	2 (5.41)	1 (4.00)	0
Segmented	11 (29.73)	8 (32.00)	9 (28.12)

Normal disc position (ND), displace with reduction (DWR), displace without reduction (DWoR)

mean styloid process lengths found for the disc status groups are shown in Fig. 5. There is a statistically significant difference between the TMJD and the non-TMJ groups in terms of the mean styloid process lengths (Table 6 and Fig. 6). The clinical information and the SP lengths of 5 patients in the non-TMJ group are summarized in Table 7. There is also a statistically significant difference between the gender groups in terms of the mean styloid process lengths. The mean styloid process length of the men is higher compared to women. Table 8 shows the distribution of the mean styloid process length by the gender groups and a summary of statistical analysis results. In this study, there were not any interventions to cause any harm or side effects.

Discussion

The limitations of this study are: first, it does not include a control group since it is not ethical to receive CBCT images containing ionizing radiation from healthy patients. So, the literature data were used to compare the results. [3]. A

Table 5 Summary of the outcome measurements and power analysis of SP length by the disc status groups

disc_status	n ^b	SP length (mm)		Power	Effect size	Alpha	Beta	p
		Mean (SD)	Min–Max					
DWoR ^a	25	35.5 (9.8)	19.9–57.1	0.26	0.171	0.05	0.7386	0.101
DWR ^a	32	34.6 (9.2)	15.1–55.3					
ND ^a	27	38.3 (8.9)	24–61.3					

^aNormal disc position (ND), displace with reduction (DWR), displace without reduction (DWoR)

^bNumber of temporomandibular joint

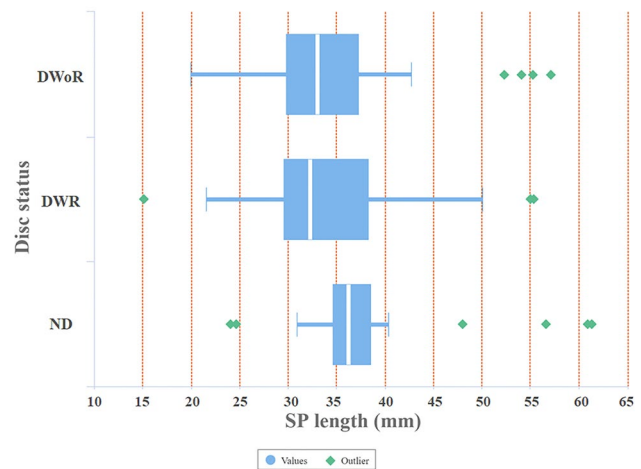


Fig. 5 Box and Whisker plots indicates the styloid process lengths in disc status groups

second limitation of the study was that the study was conducted retrospectively, so limited data were available. Lastly, many patients with calcified stylohyoid ligaments without pain have been reported in the literature. Pain in stylohyoid syndrome is not correlated with the length of calcified tissue, and although some publications have argued that the increased medial angulation of the prolonged styloid process is effective in pain [24], it is still not clear why some patients do not feel pain.

To the author’s knowledge, there are a limited number of studies investigating the styloid process elongation in TMJ disorders. In all of these studies, TMJ disorder patients were diagnosed by clinical examination by The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) [4, 11–19]. In this study, MRI (gold standard for diagnosis of TMJD) was used for the first time. It can also be monitored with soft tissue components of TMJ [10].

Although some researchers find prolonged styloid process prevalence in TMJ disorders patients [4, 12, 17, 19], some claim that these two clinical conditions are not correlated [13, 15]. In this study, it was observed that the mean styloid process length did not differ significantly among the subgroups of TMJ disorder patients. In dynamic MR images, there is a statistically significant difference in the

Table 6 Summary of the outcome measurements and power analysis of SP length by the TMJD and the non-TMJD groups

Patient_status	Number of patients	SP length (mm)		Power	Effect size	Alpha	Beta	p
		Mean (SD)	Min–Max					
TMJD	42	36.1 (9.3)	15.1–61.3	0.99	1.3	0.05	0.0001	<0.001
Non-TMJD	5	47.9 (10.8)	28.1–67.6					

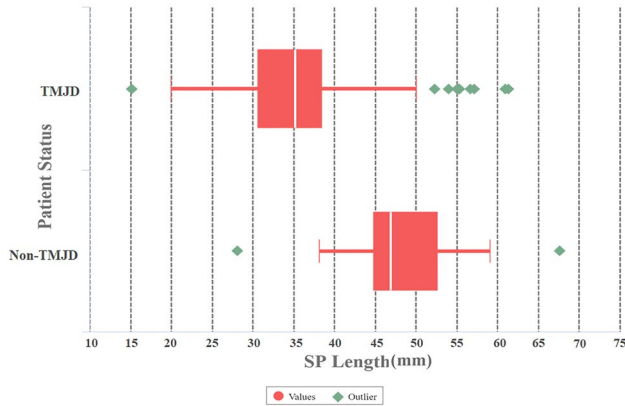


Fig. 6 Box and Whisker plots indicates the styloid process lengths in patient status groups

mean styloid process length between 5 patients (non-TMJD group) with no signs of disc displacement in either joints, but the TMJD group with disc displacement, it is shown in at least one joint. The average styloid process length of the non-TMJD group is statistically significantly higher than

the TMJD group. This may be due to the fact that these 5 patients who had no signs of disc displacement in MRI were misdiagnosed according to clinical orofacial pain symptoms. In this case, it reveals that just diagnosing TMJ disorders by clinical examination without MR imaging may lead to misdiagnosis. It also shows that the clinical symptoms of TMJ disorders in orofacial pain can easily be confused with stylo-stylohyoid syndrome. Depending on body size, the average styloid process was longer in men. This result is consistent with the findings of Krohn et al. [4].

ESP or styloid chain calcification syndromes can cause a wide range of clinical symptoms, such as pain, difficulty in swallowing, pain during head movements, foreign body sensation in the throat, and tinnitus. Almost all of them are symptoms that affect the patient’s quality of life and comfort. Moreover, ESP can cause extreme life-threatening carotid artery dissection or rupture [25]. In orofacial pain syndromes, the symptoms in SP syndromes can be easily confused as they are similar to TMJ disorders symptoms, which are usually in the immediate neighborhood. Eagle’s syndromes misdiagnosed as TMJ disorders have been reported in the literature [16]. The results of this

Table 7 The demographic characteristics, SP status and the SP lengths of 5 patients in the non-TMJD group

Subject no	Age	Sex	Side of TMJ	SP length(mm)	SP status	Clinical symptom
1	68	Female	Right	54	Pseudoarticulated	Pain
			Left	38.1	Elongated	
2	20	Male	Right	48.2	Segmented	Pain
			Left	47.6	Elongated	
3	31	Female	Right	44.3	Elongated	Pain
			Left	46.2	Elongated	
4	41	Male	Right	67.6	Segmented	Pain
			Left	59.1	Segmented	
5	36	Female	Right	28.1	Elongated	Pain
			Left	46.3	Segmented	

Table 8 Summary of the outcome measurements and power analysis of SP length by gender groups

Disc_status	n ^a	SP length (mm)		p	Power	Effect size	Alpha	Beta
		Mean (SD)	Min–Max					
Male	6	49 (12.7)	34.1–67.6	0.003	0.99	1.29	0.05	0.0001
Female	88	36.5 (9.5)	15.1–61.3					

^aNumber of temporomandibular joint

study also support these views. No disc displacement was detected in the MRI in 5 patients in the non-TMJ group. When the anamnesis recorded in the files of 5 patients in the non-TMJ group was examined again, it was found that all who presented to the clinic had pain complaints during head or jaw movements (Table 7). The complaints of these patients in the temporal regions were probably ESP-related syndromes and TMJ disorder treatment was started by making a wrong diagnosis. A study conducted by Zaki et al. [18] supported our results. In the study, they applied the treatment of TMJ disorder patients with clinical diagnosis using conservative methods (biofeedback, stress management, and intraoral appliance). While there was no significant difference in pre-treatment clinical symptoms between TMJ disorders patients with and without ESP, it was observed that painful-restricted mouth opening symptoms did not regress after treatment with ESP patients. Also, it has been stated in some previous studies that the SP angle may play a role in the formation of clinical symptoms [24]. In the evaluation of ESP or styloid chain calcification syndromes, 3D images provide more information than 2D graphics. However, the accessibility of CT or CBCT devices is more difficult. Also, its radiation dose is high. For this reason, in previous studies, it has been emphasized that there is no significant difference between the two methods in terms of evaluating SP, and panoramic entities may be sufficient to diagnose ESP [4]. In this study, CBCT was requested from patients who were previously diagnosed with TMJ disorder as a clinical diagnosis to display the hard tissue components of TMJ. For this reason, the authors made their measurements on archived CBCT images.

Conclusion

Consequently, MR imaging is the gold standard in the diagnosis of TMJ internal derangements. The clinical symptoms of TMJ disorders and Stylo-stylohyoid syndrome are similar. Care should be taken in the differential diagnosis when diagnosing these two clinical conditions, as there is a high probability of misdiagnosis.

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Compliance with ethical standards

Conflict of interest H. C. Kış, and D. S. Çabuk declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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