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RESEARCH ARTICLE

TMJ degenerative joint disease: relationships between CBCT findings, clinical symptoms, and signs

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ABSTRACT

Objectives: The relationships between cone-beam computed tomography (CBCT) findings, Temporomandibular disorder (TMD) symptoms, and signs were investigated in patients with TMJ degenerative joint disease (DJD).

Material and Methods: Adult patients with Diagnostic Criteria for TMDs (DC/TMD)-defined intra-articular conditions were enrolled and subjected to CBCT assessment. The participants were organized into three groups, namely no (NT), early (ET), and late (LT) TMJ DJD based on radiographic findings. TMD symptoms/signs were appraised using the DC/TMD methodology. Statistical analyses were performed using Chi-square/non-parametric tests and Kappa statistics ($\alpha = 0.05$).

Results: The mean age of the participants ($n = 877$) was 30.60 ± 11.50 years (86.6% women). NT, ET, and LT were observed in 39.7%, 17.0%, and 43.3% of the study sample. Significant differences in the prevalence of TMD symptoms (TMD pain, TMJ sounds, opening, and closing difficulty) and signs (TMD/TMJ pain, TMJ clicking/crepitus, and opening limitation) were discerned among the three groups ($p \leq .001$). TMD/TMJ pain and opening difficulty/limitation were more prevalent in early rather than late degenerative changes. While moderate agreements between symptoms and signs were observed for TMD pain/opening limitation, the concurrence for TMJ sounds was fair.

Conclusions: Young adults with TMJ sounds and pain should be examined with CBCT to establish the extent/progress of osseous changes.

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Introduction

Temporomandibular disorders (TMDs), characterized by pain and/or dysfunction of the Temporomandibular joints (TMJs), masticatory muscles, and supporting structures, are the second most common musculoskeletal condition after chronic lower backache [1]. According to the Diagnostic Criteria for TMDs (DC/TMD), axis I physical diagnoses comprise pain-related and/or intra-articular TMJ conditions. While pain-related TMDs (PT) include TMJ pain (arthralgia), masticatory muscle pain (myalgia), and TMD-related headaches, intra-articular TMDs (IT) consist primarily of TMJ disc displacements (DDs) and degenerative joint disease (DJD) [2]. TMJ DJD is typified by progressive articular tissue deterioration with concurrent osseous changes in condyles and/or articular eminence [3]. The prevalence of TMJ DJD in the general adult population is about 10% and ranges from 18 to 85% among TMD patients [4,5]. TMJ DJD and DDs are intricately linked and half of TMD patients with DDs have DJD. The occurrence of TMJ DJD is higher in DD without reduction (66%) than in DD with reduction (36%) [6]. Whilst the natural course of TMJ DJD is generally favourable [7], it can lead to morphological condylar changes, decreased ramal height, and progressive mandibular asymmetry or retrusion when advanced [8]. Dentofacial deformities and bite derangements might eventually develop resulting in jaw functional limitations, compromised facial appearance, psychosocial impairments, and diminished quality of life [9,10].

Though the exact etiopathogenesis of TMJ DJD has not been established [11], sustained local and systemic inflammation appears to play an important role [12–14]. Biomechanical overloading and metabolic changes can degrade articular cartilage tissues. The degraded cartilage tissues are theorized to trigger foreign body reactions within synovial cells resulting in the production of inflammatory cytokines, matrix metalloproteases, and prostaglandins that contribute to further cartilage destruction and subchondral bone re-modelling [13,14]. The innate immune system and activated macrophages have also been implicated in DJD progression [14]. Risk factors for TMJ DJD include genetics,

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age, macro and micro TMJ trauma, systemic conditions, and congenital as well as developmental abnormalities [10,11]. TMJ DJD normally involves three phases with periods of remission and repair [10,15]. The initial phase is associated with TMJ clicking and intermittent locking whereas the intermediate phase is often accompanied by TMJ pain, opening difficulty/limitation, and crepitus (grating sounds). In the final or 'burnout' phase, degenerative activity ceases and the joint is relatively stable. The entire process from initiation to the final 'burnout' phase takes about 5.5 years [15].

Following the DC/TMD protocol, TMJ DJD is inferred when there is a history of TMJ sounds with jaw movement/function and TMJ crepitus on palpation during jaw movements. However, adjunctive imaging is needed to render a definitive diagnosis as symptom history and physical examination by themselves generally have inadequate diagnostic validity for intra-articular conditions [2]. Cone-beam computed tomography (CBCT) is particularly useful for TMJ imaging due to its superior accuracy for the three-dimensional assessment of hard tissues/bone [16,17]. Hilgenberg-Sydney et al. reviewed the diagnostic validity of CBCT and concluded that it provided good images for evaluating DJD progression over time but should not be employed as a screening tool for individuals with healthy joints [18]. In a recent systematic review, Wu et al. examined the association between TMD symptoms/signs and bony changes on CBCT images in patients with TMJ DJD [19]. Only nine studies were available and all had modest sample sizes (varying from 30 to 198 patients) with a total of 697 subjects. TMJ sounds and pain were reported to have the strongest relation to various CBCT findings. Additionally, they suggested that patients with primary muscle pain should not be routinely prescribed CBCT. Given the limited studies detailing both symptoms and signs, the relatively small sample sizes of earlier work, as well as the infrequent use of standardized assessment/diagnostic protocols, further research involving larger patient samples and based on the DC/TMD is warranted.

With the aforesaid premises, the objective of this study was to investigate the relationships between CBCT findings, clinical symptoms, and signs in a large sample of TMD patients with TMJ DJD. More specifically it compared the type of TMD symptoms/signs in individuals with no, early, and late TMJ DJD, and determined the agreement between TMD symptoms and signs. The research hypotheses were: (a) substantial variances in the prevalence of TMD symptoms/signs exist among participants with no, early, and late TMJ osseous changes, and (b) the agreement between patient-reported symptoms and clinician-established signs is moderately good.

Materials and methods

Study design and participants

This observational study is part of project PKUSS-201732009 which was approved by the Biomedical Institution Review Board of the Peking University School of Stomatology and is in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained for every participant. Consecutive adult patients (≥18 years old) seeking treatment at a tertiary TMD/Orofacial Centre from May 2018 to September 2021 were screened for eligibility and enrolled. At least 358 participants were needed to compare TMD pain prevalence between IT groups. This was determined a priori with the G*Power software version 3.1.9.3 [20]. using the Z-test model (two-tailed), 0.6/0.4 proportion of IT patients without/with TMD pain, 0.05 alpha error, 95% power, and an allocation ratio of 2 derived from an earlier study [21]. Patients presenting with TMJ dysfunction and/or pain and DC/TMD-defined intra-articular conditions were included [2]. Those with prior TMJ tumor, trauma, secondary arthritis due to systematic diseases, and myalgia only were omitted along with individuals suffering from debilitating autoimmune, metabolic, and psychiatric disorders. Patients who were intellectually impaired, illiterate, or consumed central nervous agents in the previous 2 weeks were also excluded. Study involvement was strictly voluntary and informed consent was provided by all participants. At their intake visit, a comprehensive survey encompassing demographic data, medical/dental history, and the DC/TMD Symptom Questionnaire (SQ) was administered [2]. Participants were then physically examined by a TMD specialist who was trained and calibrated in the DC/TMD methodology. Participants identified with TMJ DD and/or DJD based on symptom history, physical findings, and DC/TMD algorithms were referred for CBCT assessment to verify the presence of TMJ DJD.

CBCT assessment

A three-dimensional CBCT scanner (3D Accuitomo 170, J. Morita Corporation, Kyoto, Japan) was used to acquire bilateral TMJ images at 76–80 kV and 4.2–6.0 mA. A 6 × 6 cm field of view was employed and CBCT data were reconstructed to generate multiplanar (axial, coronal, and sagittal) images with 1.0 mm slice intervals. As per the DC/TMD, TMJ DJD was confirmed if one of the following osseous changes was observed on CBCT imaging: erosions, sclerosis, osteophytes, or subchondral cysts [2]. While the loss of articular cortex continuity and surface erosions were considered early DJD alterations, sclerosis, osteophyte formation, deviations in form, and cyst-like lesions were deemed late degenerative changes [22,23]. Figure 1 displays the CBCT images of the various osseous changes and their descriptions. The CBCT images were independently assessed for early/late osseous changes by two examiners who had an inter-rater kappa of 0.79. Should the bilateral TMJs be involved, the joint with more symptoms/signs was reported. Any disparities in TMJ DJD categorization were mediated by a senior dental radiologist. The participants were eventually organized into three groups, namely no TMJ DJD (NT), early TMJ DJD (ET), and late TMJ DJD (LT).

Clinical symptoms and signs

The DC/TMD SQ provides the needed history for deriving specific TMD Axis I (physical) diagnoses. Positive responses

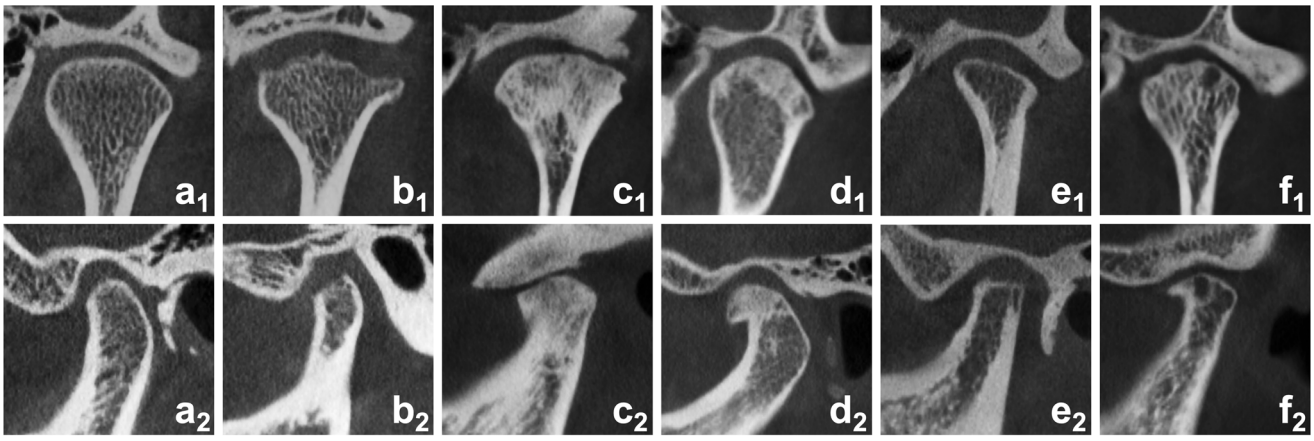

Figure 1. CBCT images of TMJs without and with DJD: (a) healthy joint, (b) erosion [decreased density of cortical bone and subcortical bone], (c) sclerosis [increased density of cortical bone extending into bone marrow], (d) osteophyte [marginal bone outgrowth of the condyle], (e) deviation in the form [loss of convex condylar form], and (f) cyst-like lesion [well circumscribed osteolytic lesion in subcortical bone without cortical destruction]. (1) indicates the coronal reconstruction while (2) indicates the sagittal reconstruction.

Table 1. Demographics and disease duration.

Demographics	No TMJ DJD (NT)	Early TMJ DJD (ET)	Late TMJ DJD (LT)	*P*-value	Post-hoc
n (%)	348 (39.7)	149 (17.0)	380 (43.3)	——	——
Age					
Mean ± SD	28.88 ± 9.84	31.99 ± 14.35	31.03 ± 11.34	**.012^**	ET, LT > NT
Median (IQR)	26.00 (10.75)	28.00 (16.50)	28.00 (12.00)		
Gender					
Women n(%)	288 (82.8)	132 (88.6)	340 (89.5)	**.022***	LT > NT
Men n(%)	60 (17.2)	17 (11.4)	40 (10.5)		
Duration (months)					
Mean ± SD	17.30 ± 29.39	9.61 ± 23.07	22.56 ± 33.57	**<.001^**	LT > NT, ET
Median (IQR)	4.00 (17.00)	6.00 (9.00)	10.00 (22.00)		

Results of ^Kruskal–Wallis/Mann–Whitney U tests and *Chi-square/Z-tests (bold indicates $p < .05$ and > indicates significant differences between groups).

to the five main questions on TMD pain, headache, TMJ noises during functional movements, closed (difficulty opening all the way), and open (difficulty closing from the wide-open position) locking were used to ascertain the presence of TMD symptoms. TMD symptoms were appraised over 30 days. TMD signs were established physically by employing the DC/TMD protocol. TMD pain, TMJ sounds, and jaw opening limitations were evaluated. TMJ and masticatory muscle pain (collectively regarded as TMD pain) were judged present if participants reported pain on palpation of the TMJs, temporalis, and masseter muscles or with maximum unassisted/assisted jaw movements. Similarly, TMJ sounds were deemed present if clicking/popping/snapping noises and/or crepitus are detected with palpation during jaw movements. Jaw opening was considered to be limited if the maximum assisted opening (passive stretch) movement was <40mm.

Statistical analysis

Statistical explorations were carried out using the SPSS statistical software Version 27.0 (IBM Corporation, Armonk, New York, USA) with the significance level set at 0.05. Qualitative data were presented as frequencies with proportions and analyzed utilizing Chi-square and post-hoc Z-tests. Quantitative data were tested for normality and reported as means/medians with standard deviations (SD)/interquartile ranges (IQR). As non-normal distribution was observed, quantitative data were examined with Kruskal–Wallis and post-hoc Mann–Whitney *U* tests. The percentage agreement between TMD symptoms and signs, explicitly TMD pain, TMJ sounds, and opening limitations were determined by counting the number of responses in agreement, dividing this by the total number of responses, and converting the outcome to a percentage. Cohen's kappa statistic was applied and the level of agreement was interpreted as follows: no (Kappa coefficient [K] ≤ 0), none to slight (0.01–0.20), fair (0.21–0.40), moderate (0.41– 0.60), substantial (0.61–0.80), and almost perfect (0.81–1.00) [24].

Results

A total of 937 potential participants were screened of which 60 met the exclusion criteria. None of the 877 eligible patients declined study participation ensuing in a 100% response rate. The mean age of the participants was 30.60 ± 11.50 years and 86.6% were women. NT, ET, and LT were observed in 39.7%, 17.0%, and 43.3% of the study sample. Substantial variances in age (ET, LT > NT) and disease duration (LT > NT, ET) were discerned among the three groups (Table 1). Table 2 presents the distribution of radiographic findings for the ET and LT groups. For the LT group, deviation in condylar form (64.2%), sclerosis (42.9%), and

Table 2. Distribution of osseous changes.

Variables	Early TMJ DJD (ET) *n* = 149	Late TMJ DJD (LT) *n* = 380	All TMJ DJD *n* = 529
Erosion n (%)	149 (100.0)	161 (42.4)	310 (58.6)
Sclerosis n (%)	——	163 (42.9)	163 (30.8)
Osteophyte *n* (%)	——	13 (3.4)	13 (2.5)
Deviation in form *n* (%)	——	244 (64.2)	244 (46.1)
Cyst-like lesion *n* (%)	——	18 (4.7)	18 (3.4)

% indicates the percentage of the column.

Table 3. Frequency of TMD symptoms.

Variables	No TMJ DJD (NT)	Early TMJ DJD (ET)	Late TMJ DJD (LT)	*P*-value*	Post-hoc
TMD pain					
YES n (%)	195 (56.0)	120 (80.5)	209 (55.0)	**<.001**	ET > NT, LT
NO n (%)	153 (44.0)	29 (19.5)	171 (45.0)		
Headache					
YES n (%)	26 (7.5)	18 (12.1)	34 (8.9)	.254	——
NO n (%)	322 (92.5)	131 (87.9)	346 (91.1)		
TMJ sounds					
YES *n* (%)	293 (84.2)	97 (65.1)	291 (76.6)	**<.001**	NT > LT > ET
NO *n* (%)	55 (15.8)	52 (34.9)	89 (23.4)		
Opening difficulty/limitation					
YES *n* (%)	152 (43.7)	84 (56.4)	115 (30.3)	**.001**	ET > NT > LT
NO *n* (%)	196 (56.3)	65 (43.6)	265 (69.7)		
Closing difficulty					
YES *n* (%)	83 (23.9)	19 (12.8)	28 (7.4)	**.001**	NT > ET, LT
NO *n* (%)	265 (76.1)	130 (87.2)	352 (92.6)		

Results of *Chi-square/Z-test (bold indicates $p < .05$ and > indicates significant differences between groups).

Table 4. Frequency of TMD signs.

Variables	No TMJ DJD (NT)	Early TMJ DJD (ET)	Late TMJ DJD (LT)	*P*-value*	Post-hoc
TMD pain					
YES *n* (%)	162 (46.6)	94 (63.1)	173 (45.5)	**<.001**	ET > NT, LT
NO *n*(%)	186 (53.4)	55 (36.9)	207 (54.5)		
TMJ pain					
YES *n* (%)	153 (44.0)	90 (60.4)	154 (40.5)	**<.001**	ET > NT, LT
NO *n* (%)	195 (56.0)	59 (39.6)	226 (59.5)		
Masticatory muscle pain					
YES *n* (%)	65 (18.7)	35 (23.5)	86 (22.6)	.330	——
NO *n* (%)	283 (81.3)	114 (76.5)	294 (77.4)		
TMJ sounds					
YES *n* (%)	185 (53.2)	71 (47.7)	215 (56.6)	.214	——
NO *n* (%)	163 (46.8)	78 (52.3)	165 (43.4)		
TMJ clicking					
YES *n* (%)	164 (47.1)	30 (20.1)	100 (26.3)	**<.001**	NT > ET, LT
NO *n* (%)	184 (52.9)	119 (79.9)	280 (73.7)		
TMJ crepitus					
YES *n* (%)	22 (6.3)	41 (27.5)	124 (32.6)	**<.001**	ET, LT > NT
NO *n* (%)	326 (93.7)	108 (72.5)	256 (67.4)		
Opening limitation					
YES *n* (%)	99 (28.4)	53 (35.6)	76 (20.0)	**<.001**	ET, NT > LT
NO *n* (%)	249 (71.6)	96 (64.4)	304 (80.0)		

TMD pain = presence of TMJ and/or masticatory muscle pain. Results of *Chi-square/Z-tests (bold indicates $p < .05$ and > indicates significant differences between groups).

erosions (42.4%) were the more commonly observed osseous changes.

The frequency of TMD symptoms and signs are reflected in Tables 3 and 4. Ranking of the prevalence of TMD symptoms was as follows: NT – TMJ sounds (84.2%) > TMD pain (56.0%) > opening difficulty (43.7%) > closing difficulty (23.9%) > headache (7.5%); ET – TMD pain (80.5%) > TMJ sounds (65.1%) > opening difficulty (56.4%) > closing difficulty (12.8%) > headache (12.1%); and LT – TMJ sounds (76.6%) > TMD pain (55.0%) > opening difficulty (30.3%) > headache (8.9%) > closing difficulty (7.4%). TMJ sounds and TMD pain were the two most regular symptoms for all groups. Significant differences in the prevalence of TMD pain (ET > NT, LT), TMJ sounds (NT > LT > ET), opening difficulty/limitation (ET > NT > LT), and closing difficulty (NT > ET, LT) were found. Regarding TMD signs, the ranking of prevalence was as follows: NT – TMJ sounds (53.2%) > TMD pain (46.6%) > opening limitation (28.4%): ET – TMD pain (63.1%) > TMJ

sounds (47.7%) > opening limitation (35.6%): and LT – TMJ sounds (56.6%) > TMD pain (45.5%) > opening limitation (20.0%). TMJ sounds and TMD pain were the two most regular signs for all groups. Significant differences in the prevalence of TMD/TMJ pain (ET > NT, LT), TMJ clicking (NT > ET, LT), TMJ crepitus (ET, LT > NT), and opening limitation (ET, NT > LT) were noted. For all groups, TMJ pain (range 40.5–60.4%) featured more prominently than masticatory muscle pain (range 18.7–23.5%). TMJ clicking was more frequently detected than TMJ crepitus for the NT group (47.1 versus 6.3%). Conversely, TMJ crepitus was more common than TMJ clicking for participants with DJD (27.5–32.6% versus 20.1–26.3%).

Table 5 reflects the percentage agreement between TMD symptoms and signs, and related Kappa coefficients (K) for the various groups. The lowest and highest Kappa values were noted for TMJ sounds in the ET group ($K = 0.20$) and opening limitation in the NT group ($K = 0.58$). When the participants were pooled together for overall analyses, moderate agreements between symptoms and signs were observed for TMD pain ($K = 0.58$) and opening limitation ($K = 0.46$). However, the agreement for TMJ sounds was only fair ($K = 0.28$).

Discussion

This is the largest study conducted to date on the associations between CBCT findings, clinical symptoms, and signs in TMD patients with TMJ DJD. When considered together, the nine prior relevant studies yielded a total of only 697 subjects [19]. As there were significant differences in the prevalence of TMD symptoms/signs among the three study groups and fair-to-moderate agreements between TMD symptoms and signs were noted, both research hypotheses were supported. Only patients with intra-articular conditions were recruited for the study to minimize unnecessary radiation exposure from CBCT imaging in individuals with healthy TMJs including those with just muscle disorders [18]. The use of the DC/TMD SQ and examination protocol provided a standardized and validated approach for establishing TMD symptoms and signs. This was also proposed by Wu et al. to enhance data homogeneity and improve both clinical and research outcomes [19]. Furthermore, the quintessential five TMD symptoms (5Ts) employed had been shown to have high sensitivity, specificity, and accuracy for detecting TMDs when referenced to the DC/TMD [25]. The predominance of women in the study sample corroborated previous work and had been explained by sex hormones, socio-cultural factors, gender disparities in emotional distress, somatization, pain sensitivity/perception, and treatment-seeking [26,27]. Variances in age and disease durations were anticipated. The ET and LT groups were older than the NT group as TMJ DJD involves three phases and progresses over time [15,28]. This also explained the longer disease duration of the LT group when compared to the ET and NT groups. In the study sample, 60.3% had TMJ DJD based on CBCT imaging.

Associations between CBCT findings and TMD symptoms/signs

TMJ DJD is often not detected clinically as radiographic evidence normally lags behind articular tissue deterioration [29]. The common late osseous changes observed radiographically were deviation in condylar form (64.2%), sclerosis (42.9%), and erosions (42.4%). Cyst-like lesions (4.7%) and osteophyte formation (3.4%) were less frequently detected. Findings agreed with those of Bae et al. who reported deviation in form (77.4%), erosions (59.7%), and sclerosis (49.1%) to be the most frequent osseous changes in East Asian patients [30].

Though both symptoms and signs describe TMDs, symptoms are subjective whereas signs are objective and observable. Except for headaches, significant differences in the prevalence of TMD symptoms were noted among the study groups. Headache attributed to TMDs is primarily muscular and patients with solely myalgia were excluded from the study. While the NT group experienced considerably more TMJ sounds and closing difficulty, the ET group reported substantially more TMD pain and opening difficulty than the other groups. Findings were consistent with the three phases of TMJ DJD with the NT, ET, and LT groups corresponding to the initial, intermediate, and late/final phases [15]. The initial phase (NT group) is associated with TMJ DDs with reduction and hence the greater occurrence of TMJ sounds (reciprocal clicking). As TMJ DDs had been linked to generalized joint laxity, the NT group may also suffer from TMJ subluxation (open-lock) explaining the higher frequency of closing difficulty [31]. The greater prevalence of TMD pain and opening difficulty noted in the ET group can be attributed to TMJ arthralgia, DD without reduction (closed-lock), and early degeneration that occur during the intermediate phase [22]. The late stage (LT group) and 'burnout' phase of TMJ DJD, which are associated with advanced osseous changes and TMJ crepitus, cannot be distinguished without serial CBCTs although TMJ pain may be indicative of active bone destruction [28].

Table 5. Percentage agreement between TMD symptoms and signs, and related Kappa values.

Variables	No TMJ DJD (NT)	Early TMJ DJD (ET)	Late TMJ DJD (LT)	All TMJ DJD	All participants
TMD pain					
% agreement	74.8%	75.3%	75.9%	75.7%	75.4%
Kappa coefficient	0.50	0.41	0.52	0.49	0.58
TMJ sounds					
% agreement	64.1%	65.8%	66.1%	66.8%	65.3%
Kappa coefficient	0.24	0.20	0.28	0.24	0.28
Opening limitation					
% agreement	80.1%	73.3%	79.7%	76.1%	78.8%
Kappa coefficient	0.58	0.49	0.48	0.47	0.46

Concerning TMD signs, the ET group presented significantly more TMJ pain and opening limitations than the NT and/or LT groups. While the NT group had a higher prevalence of TMJ clicking, the DJD (ET and LT) groups had greater frequencies of TMJ crepitus. Collectively, TMJ sounds and TMD pain, particularly TMJ crepitus and pain, were found to be associated with TMJ DJD supporting the conclusions of prior limited research [19]. CBCT examinations should hence be performed in young adults with these TMD symptoms/signs so that early/precise diagnosis and appropriate treatments can be rendered to reduce the progression of cartilage/bone destruction and promote TMJ repair/regeneration [11,32].

Agreement between TMD symptoms and signs

Moderate agreements between TMD symptoms/signs were discerned for TMD pain and opening limitation whilst the concurrence for TMJ sounds was fair. Findings confirmed the consistency of the DC/TMD protocol and the utility of the 5Ts for screening TMDs. Nevertheless, the evaluation of TMJ sounds by both patients and clinicians remains somewhat problematic and can be influenced by TMD pain/mouth opening and prejudiced by disease experience and perception. This was demonstrated by the low sensitivity of DC/TMD procedures for assessing TMJ DD with reduction, DD without reduction without limited opening, and DJD [2]. The aforesaid together with the low correlation between TMJ sounds and the degree of TMJ disc displacements/extent of TMJ degeneration accounted for the fair agreement observed [33–36]. Adjunctive diagnostic imaging, including magnetic resonance imaging (MRI) and CBCT, is thus necessary to confirm the provisional clinical diagnosis of intra-articular TMDs [2]. While CBCT is the reference technique for TMJ hard tissues, MRI is the method of choice for TMJ soft tissues [37]. Besides the observation of disc position and morphology, MRIs also allow for the detection of intra-articular fluid accumulation in multiple planes [38].

Study limitations

This study has some design and technical limitations. First, healthy TMJs, which are ideal controls, were excluded from the study to circumvent needless CBCT radiation. Second, the fluctuating nature of TMD symptoms and signs was not contemplated in the cross-sectional design [39]. Furthermore, pain intensity on TMJ and muscle palpation was not appraised and should be considered for follow-up work. Third, like previous parallel studies, radiographic findings could not be specifically defined due to the lack of standardized CBCT imaging analysis criteria [19]. Fourth, as most of the patients were young adults, the findings cannot be generalized and extrapolated to middle-aged and old adults. Lastly, the magnitude of the Kappa coefficient (K) can be affected by several factors including disease prevalence, response bias, and non-independence of TMD symptoms/signs [24].

Conclusion

In this large sample of patients with intra-articular TMDs, 17.0% and 43.3% exhibited early and late TMJ DJD respectively. Significant differences in the prevalence of TMD symptoms (TMD pain, TMJ sounds, opening, and closing difficulty) and signs (TMD/TMJ pain, TMJ clicking/crepitus, and opening limitation) were observed among participants with no, early, and late TMJ osseous changes. TMD/TMJ pain and opening difficulty/limitation were more rampant in early rather than late DJD and may be indicative of active bone destruction. Therefore, TMD-related pain symptoms/signs do not correlate with the extent of osseous changes. Although moderate agreements between symptoms and signs were observed for TMD pain and opening limitation, the concurrence for TMJ sounds was fair. In the clinical setting, young adults with TMJ sounds and TMD pain, particularly TMJ crepitus and pain, should be examined with CBCT. Only then can early and accurate TMJ DJD diagnoses be made facilitating timely therapeutic interventions to minimize further TMJ deterioration and encourage TMJ repair/regeneration.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

[1] Research NIoDaC. Facial pain. Available from: https://www.nidcr.nih.gov/research/data-statistics/facial-pain. 2022.
[2] Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: recommendations of the international RDC/TMD consortium network* and orofacial pain special interest group†. J Oral Facial Pain Headache. 2014;28(1):6–27.
[3] Peck CC, Goulet JP, Lobbezoo F, et al. Expanding the taxonomy of the diagnostic criteria for temporomandibular disorders. J Oral Rehabil. 2014;41(1):2–23.
[4] Valesan LF, Da-Cas CD, Réus JC, et al. Prevalence of temporomandibular joint disorders: a systematic review and meta-analysis. Clin Oral Investig. 2021;25(2):441–453.
[5] Pantoja LLQ, de Toledo IP, Pupo YM, et al. Prevalence of degenerative joint disease of the temporomandibular joint: a systematic review. Clin Oral Investig. 2019;23(5):2475–2488.
[6] Silva MAG, Pantoja LLQ, Dutra-Horstmann KL, et al. Prevalence of degenerative disease in temporomandibular disorder patients with disc displacement: a systematic review and meta-analysis. J Craniomaxillofac Surg. 2020;48(10):942–955.
[7] Manfredini D, Favero L, Gregorini G, et al. Natural course of temporomandibular disorders with low pain-related impairment: a 2-to-3-year follow-up study. J Oral Rehabil. 2013;40(6):436–442.
[8] Mercuri LG. Osteoarthritis, osteoarthrosis, and idiopathic condylar resorption. Oral Maxillofac Surg Clin North Am. 2008;20(2):169–183.

[9] Song YL, Yap AU. Orthognathic treatment of dentofacial disharmonies: its impact on temporomandibular disorders, quality of life, and psychosocial wellness. Cranio. 2017;35(1):52–57.
[10] Kalladka M, Quek S, Heir G, et al. Temporomandibular joint osteoarthritis: diagnosis and long-term conservative management: a topic review. J Indian Prosthodont Soc. 2014;14(1):6–15.
[11] Wang XD, Zhang JN, Gan YH, et al. Current understanding of pathogenesis and treatment of TMJ osteoarthritis. J Dent Res. 2015;94(5):666–673.
[12] Abramoff B, Caldera FE. Osteoarthritis: pathology, diagnosis, and treatment options. Med Clin North Am. 2020;104(2):293–311.
[13] Feng SY, Lei J, Chen HM, et al. Increased chemokine RANTES in synovial fluid and its role in early-stage degenerative temporomandibular joint disease. J Oral Rehabil. 2020;47(9):1150–1160.
[14] Berenbaum F. Osteoarthritis as an inflammatory disease (osteoarthritis is not osteoarthrosis!). Osteoarthritis Cartilage. 2013;21(1):16–21.
[15] Stegenga B, de Bont LG, Boering G, et al. Tissue responses to degenerative changes in the temporomandibular joint: a review. J Oral Maxillofac Surg. 1991;49(10):1079–1088.
[16] Liang X, Liu S, Qu X, et al. Evaluation of trabecular structure changes in osteoarthritis of the temporomandibular joint with cone beam computed tomography imaging. Oral Surg Oral Med Oral Pathol Oral Radiol. 2017;124(3):315–322.
[17] Ma RH, Yin S, Li G. The detection accuracy of cone beam CT for osseous defects of the temporomandibular joint: a systematic review and meta-analysis. Sci Rep. 2016;6:34714.
[18] Hilgenberg-Sydney PB, Bonotto DV, Stechman-Neto J, et al. Diagnostic validity of CT to assess degenerative temporomandibular joint disease: a systematic review. Dentomaxillofac Radiol. 2018;47(5):20170389.
[19] Wu M, Almeida FT, Friesen R. A systematic review on the association between clinical symptoms and CBCT findings in symptomatic TMJ degenerative joint disease. J Oral Facial Pain Headache. 2021;35(4):332–345.
[20] Faul F, Erdfelder E, Lang AG, et al. G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175–191.
[21] Lei J, Yap AU, Zhang M, et al. Temporomandibular disorder subtypes, emotional distress, impaired sleep, and oral health-related quality of life in asian patients. Community Dent Oral Epidemiol. 2021;49(6):543–549.
[22] Lei J, Han J, Liu M, et al. Degenerative temporomandibular joint changes associated with recent-onset disc displacement without reduction in adolescents and young adults. J Craniomaxillofac Surg. 2017;45(3):408–413.
[23] 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(8):472–477.
[24] Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. Phys Ther. 2005;85(3):257–268.
[25] Yap AU, Zhang MJ, Zhang XH, et al. Viability of the quintessential 5 temporomandibular disorder symptoms as a TMD screener. Oral Surg Oral Med Oral Pathol Oral Radiol. 2022;133(6):643–649.
[26] Yap AU, Sultana R, Natu VP. Stress and emotional distress: their associations with somatic and temporomandibular disorder-related symptoms. Psychol Health Med. 2022;27(4):876–887.
[27] Bueno CH, Pereira DD, Pattussi MP, et al. Gender differences in temporomandibular disorders in adult populational studies: a systematic review and meta-analysis. J Oral Rehabil. 2018;45(9):720–729.
[28] Song H, Lee JY, Huh KH, et al. Long-term changes of temporomandibular joint osteoarthritis on computed tomography. Sci Rep. 2020;10(1):6731.
[29] Dijkgraaf LC, Spijkervet FK, de Bont LG. Arthroscopic findings in osteoarthritic temporomandibular joints. J Oral Maxillofac Surg. 1999;57(3):255–268. discussion 69–70.
[30] Bae S, Park MS, Han JW, et al. Correlation between pain and degenerative bony changes on cone-beam computed tomography images of temporomandibular joints. Maxillofac Plast Reconstr Surg. 2017;39(1):19.
[31] Boboc AM, De Stefano A, Impellizzeri A, et al. Correlation between generalised joint hypermobility and temporomandibular joint disc displacement in adolescent patients: magnetic resonance imaging study. Eur J Paediatr Dent. 2022;23(2):106–110.
[32] Lei J, Yap AU, Liu MQ, et al. Condylar repair and regeneration in adolescents/young adults with early-stage degenerative temporomandibular joint disease: a randomised controlled study. J Oral Rehabil. 2019;46(8):704–714.
[33] Yuan S, Liu Y, Deng K, et al. Correlation of clinical manifestations and condylar morphology of patients with temporomandibular degenerative joint diseases [published online ahead of print]. Cranio. 2022;1–8.
[34] Matsubara R, Yanagi Y, Oki K, et al. Assessment of MRI findings and clinical symptoms in patients with temporomandibular joint disorders. Dentomaxillofac Radiol. 2018;47(4):20170412.
[35] Cömert Kiliç S, Kiliç N, Sümbüllü MA. Temporomandibular joint osteoarthritis: cone beam computed tomography findings, clinical features, and correlations. Int J Oral Maxillofac Surg. 2015;44(10):1268–1274.
[36] Eriksson L, Westesson PL, Rohlin M. Temporomandibular joint sounds in patients with disc displacement. Int J Oral Surg. 1985;14(5):428–436.
[37] Tresoldi M, Dias R, Bracci A, et al. Magnetic resonance imaging evaluation of closed-mouth TMJ disc-condyle relationship in a population of patients seeking for temporomandibular disorders advice. Pain Res Manag. 2021;2021:5565747.
[38] Litko-Rola M, Szkutnik J, Różyło-Kalinowska I. The importance of multisection sagittal and coronal magnetic resonance imaging evaluation in the assessment of temporomandibular joint disc position. Clin Oral Investig. 2021;25(1):159–168.
[39] Nilsson IM, List T, Drangsholt M. Incidence and temporal patterns of temporomandibular disorder pain among Swedish adolescents. J Orofac Pain. 2007;21(2):127–132.