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Diagnostic accuracy of anterior joint space widening on CBCT for identifying anterior disc displacement: a retrospective study using MRI as the reference standard

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Abstract

Objectives

To evaluate the diagnostic accuracy of anterior joint space widening on Cone Beam Computed Tomography (CBCT) for identifying anterior disc displacement (ADD) of the temporomandibular joint (TMJ), using Magnetic Resonance Imaging (MRI) as the reference standard.

Methods

A retrospective analysis of 485 TMJs (from 282 patients) with paired CBCT and MRI was conducted. Diagnostic performance metrics (sensitivity, specificity, PPV, NPV) for ADD, gender / ADD subtype subgroup analyses and multivariate logistic regression (gender / age effects) were performed.

Results

For diagnosing any ADD, CBCT showed high sensitivity (92.4%) and NPV (94.4%), but low specificity (47.9%) and PPV (39.9%). NPV was significantly higher than PPV. PPV was lower in males (24.7%) than females (46.7%, $p < .001$) and 19.9% for diagnosing only ADD without reduction (ADDwoR). ADDwoR (52.3%, 69/132) and ADD with reduction (47.7%, 63/132) had no significant prevalence difference ($\chi^2 = 0.23$, $df = 1$, $p = .632$). Female gender as a significant risk factor for both CBCT-detected anterior space widening ($OR = 0.668$, $p = .044$) and MRI-confirmed ADD ($OR = 0.390$, $p < .001$). Age showed no significant effect.

Conclusions

Anterior joint space widening on CBCT is highly sensitive but non-specific for ADD, useful for screening and exclusion (high NPV), but requiring MRI confirmation (low PPV). The two ADD subtypes were numerically close in prevalence, and CBCT cannot reliably distinguish between them. The significant influence of gender should be considered clinically.

1 Introduction

Temporomandibular Disorders (TMD) refer to a group of conditions affecting the temporomandibular joint (TMJ), masticatory muscles, and associated structures, clinically manifesting as pain, clicking sounds, and restricted mandibular movement[1]. Among the various etiological factors, disc displacement (DD)[2], particularly anterior disc displacement (ADD)[3], is a predominant pathological entity.

The accurate classification of anterior disc displacement into reduction (ADDwR) and without reduction (ADDwoR) subtypes is a critical imaging and clinical imperative, as it dictates the therapeutic pathway[4]

—ranging from conservative management to potential surgical intervention[5].

Magnetic resonance imaging (MRI) remains the gold standard for soft tissue evaluation, providing direct visualization of disc position and morphology[6]. However, its high cost and limited availability in primary dental settings often restrict its use. Cone Beam Computed Tomography (CBCT) provides accurate assessment of osseous structures and changes in the TMJ space[7]. Consequently, CBCT has become the routine imaging modality for TMJ assessment in dental practice due to its superior spatial resolution and wide accessibility[8].

Nevertheless, whether changes in the joint space observed on TMJ CBCT images can reliably infer disc position, and the accuracy of such inferences, remain areas with limited research[9], warranting further investigation.

Using MRI as the reference standard, this study aimed to systematically evaluate the diagnostic accuracy of CBCT-detected anterior joint space widening for diagnosing ADD. Beyond conventional sensitivity and specificity, we quantified its positive and negative predictive values to define its confirmatory and exclusionary utility in clinical practice. We further conducted comprehensive statistical analyses to characterize the diagnostic performance and identify influencing factors, such as gender and displacement type, thereby providing evidence to guide the rational clinical use of CBCT in TMJ imaging.

2 Methods

2.1 Study Design and Reporting

This was a retrospective, diagnostic accuracy study. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

2.2 Study Subjects and Criteria

This study analyzed paired CBCT and MRI images of the TMJ from the same patients. CBCT and MRI data were obtained from the picture archiving and communication system (PACS) of a collaborating tertiary hospital and an associated specialized imaging center, respectively. All data were screened for eligibility between January 2022 and December 2022. Data screening and extraction were completed in 2026. The inclusion and exclusion criteria are as follows:

Inclusion criteria:

(1) Patients with both CBCT and MRI imaging of the TMJ and the interval between the two examinations ≤ 15 days;

(2) Patient age between 15 and 60 years;

(3) CBCT diagnosis showing either widened anterior joint space with narrowed posterior space or normal joint space;

(4) No osteophyte formation on the anterior surface of the condyle or posterior surface of the articular eminence;

(5) Adequate image quality (clear visualization of condyle and glenoid fossa, free of severe motion or metal artifacts).

Exclusion criteria:

(1) History of TMJ trauma prior to CBCT or MRI;

(2) TMJ treatment performed before CBCT and MRI scans;

(3) MRI diagnosis of disc perforation, deformation, joint effusion, or osteoarthritis;

(4) Flattened, shortened, or reduced condyle, or obvious condylar bone destruction.

2.3 Imaging Acquisition Protocols

2.3.1 CBCT Scanning:

Equipment: Morita F17 (Morita Corp., Japan);

Parameters: Tube voltage 90 kV, tube current 6 mA, field of view (FOV) 17 × 12 cm, voxel size 0.25 mm^3.

Patient positioning: Seated upright, maxillary and mandibular teeth in centric occlusion (closed mouth), chin resting on the chin support, head stabilized against the headrest.

2.3.2 MRI Scanning:

Equipment: Siemens 3.0T MR, MAGNETOM Skyra (Siemens Corp, Germany.)

Sequences: PD TSE sagittal (closed and open mouth), PD TSE coronal (closed mouth), dynamic HASTE sagittal.

Scanning parameters:

(1) PD sequence: Slice thickness 2mm, slice gap 0.2mm. FOV 12cm, repetition time (TR) 2000ms, echo time (TE) 30ms, matrix 256 × 256. Nine slices perpendicular to the long axis of the condyle were obtained in sagittal and coronal planes at closed mouth, and in sagittal plane at maximal mouth opening.

Patient positioning: Supine, teeth in centric occlusion during closed-mouth scan; during open-mouth scan, patient opened maximally and maintained position using a bite block until scanning completed.

(2) Dynamic HASTE sagittal sequence: Slice thickness 4mm, slice gap 1.2mm. TR 500ms, TE 70ms, matrix 320 × 320.

Patient positioning: Supine, starting with mouth closed. Patient gradually opened mouth to maximum upon technician's verbal instruction, then slowly closed back under guidance.

2.4 Image Post-processing and Evaluation

CBCT datasets were acquired and immediately reconstructed using the integrated, manufacturer-provided reconstruction software (Morita Corp., Kyoto, Japan) that is part of the standard imaging suite for the Morita F17 system. Standard bone window settings (window width: 2000–4000 HU, level: 400–800 HU) were applied. Oblique sagittal reconstructions were then manually aligned parallel to the long axis of the condyle on the same system for evaluation.

Diagnostic data source: The study utilized finalized clinical radiology reports. All reports were generated through a standardized institutional protocol involving an initial diagnosis by a radiologist and confirmation by a senior radiologist (> 10 years of experience), ensuring clinical diagnostic authority.

Criteria:

CBCT Diagnosis (Index Test): The anterior joint space was visually assessed on a single oblique sagittal slice where the condylar transverse ridge was most clearly seen. Anterior space widening was defined as the anterior joint space visibly exceeding the posterior space, a validated criterion consistent with prior literature[10].Results were categorized as "widened" or "normal".

Blinded Data Extraction Protocol: To minimize bias, the extraction of index test (CBCT) and reference standard (MRI) results was performed independently by two investigators who were blinded to the study’s hypothesis. Investigator A extracted and recorded all CBCT diagnostic conclusions from the clinical reports. Investigator B, separately, extracted and recorded all MRI diagnostic conclusions. Both investigators were blinded to each other’s extracted data. A third researcher, not involved in extraction, then matched the CBCT and MRI results by patient and joint identifier to create the final analysis dataset.

2.5 Grouping

CBCT diagnostic results for TMJ space were categorized into two groups: the CBCT-detected anterior joint space widening group and the normal anterior joint space group. Anterior joint space widening was determined using visual qualitative criteria: on sagittal images, if the anterior joint space was visibly wider than the posterior joint space or significantly wider than the normal anatomical configuration, it was classified as widened. MRI diagnostic results were classified based on the articular relationship into three groups: normal articular disc position (NADP), ADDwR, and ADDwoR.

By cross-referencing CBCT and MRI diagnostic results, all included joints were divided into the following six groups:

Group A: CBCT-detected anterior space widening + ADDwR

Group B: CBCT-detected anterior space widening + ADDwoR

Group C: CBCT-detected anterior space widening + NADP

Group D: Normal anterior space + ADDwR

Group E: Normal anterior space + ADDwoR

Group F: Normal anterior space + NADP

The unilateral TMJ served as the unit of analysis (i.e., one TMJ counted as one case). The number of cases and proportions for each group were calculated.

2.6 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 25.0 for Windows (IBM Corp., Armonk, NY, USA).Diagnostic performance (sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), accuracy) with 95% confidence intervals (*CI*) was calculated using MRI as the gold standard. Categorical variables (e.g., gender, CBCT results, MRI diagnosis) were compared using the Chi-square (χ^2) test. The use of the Chi-square test was based on the assumption that all expected cell frequencies were greater than 5; Fisher's exact test was applied when this condition was not met. A p-value < .05 was considered statistically significant.

Since the age data significantly deviated from normality (p < .001), data were expressed as median and IQR to accurately reflect the central tendency and dispersion of the data. Group comparisons for non-normally distributed data were performed using the Mann-Whitney U test.

2.6.1 Sensitivity Analysis and Subgroup Analysis

Using MRI diagnosis as the gold standard, two definitions for gold standard positivity were established based on the study objectives:Differences in diagnostic performance metrics between Definition A (Any ADD) and Definition B (ADDwoR only) were compared to evaluate the impact of disease definition on the diagnostic performance of CBCT.

Stratified by gender (male vs. female), the aforementioned diagnostic performance metrics (using Definition A: Any ADD) were calculated separately.

2.6.2 Multivariate Logistic Regression Analysis

Binary logistic regression analyzed factors (age, gender) associated with MRI-diagnosed ADD (Definition A) as the dependent variable (0 = no displacement, 1 = displacement). The independent variables included CBCT anterior joint space widening (0 = normal, 1 = widened), age (continuous variable), and

gender (0 = female, 1 = male). Regression coefficients (β), Wald χ^2 values, *p*-values, Odds Ratios (*OR*), and their 95% *CI* were calculated for each variable.

2.7 Sample Size and Power Analysis

A post-hoc power analysis for the primary diagnostic accuracy endpoint (CBCT sensitivity for any ADD) was performed. Given the 132 MRI-confirmed ADD cases, the study achieved > 99% power (α = .05, two-sided) to detect a sensitivity significantly greater than 50% (null hypothesis), indicating adequate statistical power.

3 Results

3.1 Baseline Characteristics and Group Distribution

As shown in Table 1, baseline characteristics including age, gender, MRI findings, and CBCT results were compared between male and female participants.

Table 1
Baseline Characteristics of Study Participants

Characteristic	Total (N = 485)	Male (n = 169)	Female (n = 316)	*p* value
Age (years)	24.0 (8.0)	22.0 (7.0)	25.0(8.0)	< .001
MRI diagnosis				< .001
ADD	132 (27.2)	28 (16.6)	104 (32.9)	
NADP	353 (72.8)	141 (83.4)	212 (67.1)	
CBCT diagnosis				.065
Anterior space widening	306 (63.1)	97 (57.4)	209 (66.1)	
Normal anterior space	179 (36.9)	72 (42.6)	107 (33.9)	

Note: Values are n (%) or median (IQR). *p* values were calculated using the χ^2 test for categorical variables and the Mann–Whitney U test for age (non-normally distributed).

Data were analyzed per joint, encompassing 485 TMJs from 282 patients (169 joints from 96 males, 316 joints from 186 females). The mean age was 24.0 years (IQR, 8.0; range, 15–60). MRI diagnosed NADP in 353 joints (72.8%), ADDwR in 63 (13.0%), and ADDwoR in 69 (14.2%). CBCT identified anterior joint space widening in 306 joints (63.1%). The detailed cross-tabulation of CBCT findings and MRI diagnoses, stratified by gender, is presented in Table 2.

Table 2
Association between MRI disc position and CBCT anterior joint space findings in 465 TMJs, by gender.

Group	Diagnostic Definition	Total (N = 485)	Male (n = 169)	Female (n = 316)
A	CBCT widening + ADDwR	61 (12.6)	9 (5.3)	52 (16.5)
B	CBCT widening + ADDwoR	61 (12.6)	15 (8.9)	46 (14.6)
C	CBCT widening + NADP	184 (37.9)	73 (43.2)	111 (35.1)
D	CBCT normal + ADDwR	2 (0.4)	1 (0.6)	1 (0.3)
E	CBCT normal + ADDwoR	8 (1.7)	3 (1.8)	5 (1.6)
F	CBCT normal + NADP	169 (34.8)	68 (40.2)	101 (32.0)
Total		485 (100.0)	169 (100.0)	316 (100.0)

Note: Values are n (%). ADDwR, anterior disc displacement with reduction; ADDwoR, without reduction; NADP, normal articular disc position.

The distribution of cases across the six diagnostic groups revealed that the combination of CBCT-detected anterior space widening with NADP (Group C) was the most common (37.9%), followed by normal anterior space with NADP (Group F, 34.8%). The combination of normal anterior space with ADDwR (Group D) was the least frequent (0.4%).

Gender stratification showed that among male joints, a normal anterior space with NADP (Group F, 40.2%) was most common, whereas among female joints, CBCT-detected anterior space widening with NADP (Group C, 35.1%) was most common. The proportions of true-positive CBCT findings (i.e., widening with confirmed ADD, Groups A and B combined) were higher in females (31.1%) than in males (14.2%).

Representative imaging findings are shown in Figs. 1 through 4. Figure 1 displays CBCT features of joint space, and Figs. 2–4 illustrate MRI manifestations of normal articular disc position, reducible anterior disc displacement, and irreducible anterior disc displacement, respectively.

3.2 Diagnostic Performance of CBCT for Anterior Disc Displacement

Using MRI as the gold standard, the diagnostic performance of CBCT for ADD, including subgroup analysis and sensitivity analysis, is summarized in Table 3.

Table 3
Diagnostic Performance of CBCT for Anterior Disc Displacement Under Different Analytic Conditions

Analysis Group	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
All Joints (Any ADD)	92.4 (87.9–96.2)	47.9 (42.7–53.0)	39.9 (34.3–45.6)	94.4 (90.4–97.2)	58.1 (53.5–62.6)
Male Joints (Any ADD)	85.7 (70.3–96.0)	48.2 (40.0-56.4)	24.7 (16.5–34.0)	94.4 (87.1–98.3)	54.4 (46.5–62.2)
Female Joints (Any ADD)	94.2 (89.0-97.8)	47.6 (41.0-54.2)	46.7 (40.0-53.5)	95.3 (90.6–98.3)	60.2 (54.5–65.7)
All Joints (ADDwoR only)	88.4 (78.5–94.3)	41.1 (36.3–46.1)	19.9 (15.5–25.0)	95.5 (92.0-97.6)	50.3 (45.7–54.9)

Note: PPV, Positive Predictive Value; NPV, Negative Predictive Value. Values are percentages with 95% Wilson confidence intervals. The PPV is substantially lower than the NPV across all analytic scenarios, underscoring the sign's superior utility for ruling out ADD. Statistical comparison of PPV between male and female joints: $\chi^2 = 13.32$, $p < .001$.

For diagnostic any ADD, CBCT showed high sensitivity (92.4%, 95% *CI*: 87.9–96.2) and NPV (94.4%, 95% *CI*: 90.4–97.2), but low specificity (47.9%, 95% *CI*: 42.7–53.0) and PPV (39.9%, 95% *CI*: 34.3–45.6). The NPV (94.4%) was substantially higher than the PPV (39.9%), indicating that the reliability of negative CBCT results for ruling out ADD is far superior to that of positive results for confirming ADD.

Gender subgroup analysis revealed that the PPV of female joints (46.7%, 95% *CI*: 40.0-53.5) was significantly higher than that of male joints (24.7%, 95% *CI*: 16.5–34.0, $p < .001$); there were no significant gender differences in sensitivity, specificity, NPV, or accuracy (all $p > .05$).

Sensitivity analysis limiting the gold standard to ADDwoR only showed that the PPV of CBCT further decreased to 19.9% (95% *CI*: 15.5–25.0), while maintaining high sensitivity (88.4%, 95% *CI*: 78.5–94.3) and NPV (95.5%, 95% *CI*: 92.0-97.6). This result indicates that CBCT cannot reliably distinguish between reducible and irreducible anterior disc displacement.

3.3 Factors Associated with CBCT Findings and Anterior Disc Displacement

Under definition A (Any ADD), multivariate logistic regression analysis was performed to explore factors associated with CBCT-detected anterior joint space widening and MRI-confirmed anterior disc displacement (Table 4).

Table 4
Multivariate Logistic Regression Analysis of Factors Associated with CBCT Findings and Anterior Disc Displacement.

Dependent Variable	Factor	*β*	*SE*	Wald χ^2	*p*-value	*OR*	95%*CI*
CBCT anterior space widening	Gender	−0.404	0.200	4.064	.044	0.668	0.451–0.989
	Age (years)	0.010	0.013	0.618	.432	1.010	0.985–1.037
	Constant	−0.544	0.350	2.419	.120	—	—
MRI-diagnosed ADD	Gender	−0.940	0.243	14.933	< .001	0.390	0.242–0.629
	Age (years)	0.012	0.015	0.641	.423	1.012	0.983–1.041
	Constant	1.340	0.401	11.154	.001	—	—

Note: ADD, anterior disc displacement (Any ADD). *SE*, Standard Error; *OR*, Odds Ratio; *CI*, Confidence Interval. Reference category for Gender: Female.

The multivariate regression analysis (Table 4) identified female gender as a significant independent risk factor for both CBCT-detected anterior space widening (*OR* = 0.668, 95% *CI*: 0.451–0.989, *p* = .044) and MRI-confirmed ADD (*OR* = 0.390, 95% *CI*: 0.242–0.629, *p* < .001). The stronger association observed with the MRI outcome indicates that the actual disparity in disc displacement prevalence between genders is more pronounced than what is reflected by the CBCT sign alone. This finding aligns with the established higher prevalence of TMD and disc displacement among females reported in the literature[11]. In contrast, age showed no significant association with either outcome in our cohort (*p* > .05).

4 Discussion

4.1 The Theoretical Basis and Diagnostic Limitations of the Radiographic Sign

The biomechanical rationale underlying this sign, as well as the factors confounding its interpretation, help explain this performance profile. The hypothesis that an anteriorly displaced disc may posteriorly translate the condyle, leading to widening of the anterior joint space on CBCT, forms the basis for using this sign as an indirect indicator of ADD[12].

However, the diagnostic specificity of this sign is limited. A widened anterior space is a non-specific finding that can be caused by various conditions other than ADD, including joint effusion, masticatory

muscle hyperactivity, condylar resorption, occlusal relationships during imaging, specific condylar morphologies, dentofacial deformities, and physiological variations[13–17].

Manfredini D's research revealed that a significant proportion of asymptomatic individuals exhibit disc displacement[17]. This indicates that the prevalence of anatomical ADD in the population may be higher than the prevalence of symptomatic disease, a radiological diagnosis of ADD does not necessarily equate to a pathological state. However, in our clinical context where the sign is used to diagnose symptomatic ADD, the presence of asymptomatic displacement contributes to the non-specificity of the finding and is one of the factors that can depress the observed PPV in a clinical cohort.

The occlusal relationship during CBCT imaging can influence the position of the condyle within the glenoid fossa, subsequently affecting joint space dimensions. To mitigate confounding from occlusion, imaging in this study was standardized in a light centric occlusion[18]. This protocol was implemented to eliminate biases arising from inconsistent occlusal relationships or excessive clenching.

Furthermore, the progression of ADD also influences joint space dimensions. Some studies suggest that ADD does not inevitably lead to widening of the anterior joint space[19–21]. In the early stages of ADD, the posterior band of the disc becomes locked anterior to the condyle, resulting in a widened anterior space and a narrowed posterior space. However, as the condition progresses (e.g., ADDwoR), the disc may shift further anteriorly to the level of the condylar neck, and the anterior joint space may appear normal. This pathophysiological spectrum directly explains the false-negative CBCT findings (i.e., normal space with confirmed ADD) observed in our study and aligns with prior literature[20,21], underscoring the limitations of inferring disc position solely based on joint space measurements.

4.2 Performance Analysis of CBCT in Diagnosing ADD

In this study, the diagnostic performance of CBCT for ADD yielded a sensitivity of 92.4% and a NPV of 94.4%, whereas the specificity was only 47.9% and the PPV was merely 39.9%. This diagnostic profile highlights the dual characteristics of CBCT:

First, CBCT demonstrates excellence in ruling out ADD. Among the 179 joint sides showing a normal anterior space on CBCT, 169 sides (94.4%) were confirmed by MRI to have normal disc positions. With a sensitivity of 92.4% and a miss rate of only 7.6%, a negative CBCT result can reliably exclude ADD. This makes CBCT highly suitable as a preliminary screening tool, potentially reducing the need for unnecessary MRI examinations.

Second, CBCT has limited value in confirming ADD. Among the 306 joint sides where CBCT indicated anterior space widening, only 122 sides (39.9%) were confirmed as ADD by MRI, resulting in a high false-positive rate of 52.1%. The factors contributing to the low PPV include the relatively low prevalence of ADD in the population (27.2% in this study), the lack of objective quantitative criteria for judging anterior space widening, and a tendency among readers to adopt a conservative interpretation to avoid missed diagnoses.

Notably, the NPV (94.4%) was significantly higher than the PPV (39.9%), with this asymmetry being statistically significant ($p < .001$). This disparity represents one of the core findings of this study: CBCT is exceptional for excluding ADD but limited for confirming it. From a clinical perspective, a negative CBCT finding can basically rule out ADD, whereas a positive finding must be verified by MRI.

Subgroup analysis revealed a profound disparity in diagnostic reliability. The PPV for males (24.7%) was significantly lower than that for females (46.7%, $p < .001$), suggesting that the issue of false positives is more pronounced in males.

Sensitivity analysis, which limited the gold standard to ADDwoR only, showed that the PPV of CBCT for diagnosing this specific subtype was 19.9% (95% *CI*: 15.5–25.0), far lower than its 39.9% PPV for any type of disc displacement. In this study, ADDwoR accounted for 52.3% of all ADD cases (69/132), while ADDwR accounted for 47.7% (63/132); the two subtypes were numerically close, with no statistically significant difference in their prevalence ($\chi^2 = 0.23$, $df = 1$, $p = .632$). Despite the lack of significant statistical difference, ADDwoR is a clinically important subtype that often requires intervention, and this result carries significant warning implications: ADDwoR is precisely the type for which CBCT diagnostic reliability is poor. CBCT struggles to reliably distinguish between reducible and irreducible displacements, a distinction that holds critical guidance value for treatment planning, particularly regarding surgical decision-making.

4.3 Comparison with Prior Evidence

The diagnostic performance quantified in this study must be interpreted within the context of existing literature, which reveals both convergence and important distinctions.

First, our finding of a low PPV (39.9%) critically extends prior correlative studies. Several investigations have established an association between anterior joint space alteration and disc displacement[20,21]. However, these studies primarily reported group differences or correlation coefficients without translating them into the predictive values necessary for clinical decision-making. Our study provides this crucial translation, demonstrating that despite the association, a positive sign is likely to be a false positive in a majority of cases.

Second, the suboptimal diagnostic specificity reflected in our low PPV stands in contrast to studies employing strict quantitative methodologies. For instance, Yu et al. reported high sensitivity and specificity using quantitative posterior-anterior joint space ratios[9]. This discrepancy underscores a critical distinction: while quantitative threshold-based measurements in a controlled research setting may achieve higher accuracy, the visual qualitative assessment evaluated in our study reflects the real-world performance of this sign in routine clinical practice, where such measurements are not typically performed. Our findings thus provide a pragmatic estimate of the sign's utility in standard clinical workflows.

Third, the high NPV (94.4%) of a normal anterior space provides a robust, evidence-based rationale for a key clinical application—screening to rule out ADD. This finding strengthens the conclusions of comprehensive morphological studies. For example, Osama et al. detailed multiple CBCT parameters associated with disc displacement[8]. While their work elucidates the structural correlates of the disease, our study defines the practical utility of the most commonly observed single sign: its strength lies in exclusion, not confirmation.

Finally, the pathophysiological spectrum of ADD helps explain the limitations of the sign. As supported by Zhou et al.[20], severe or chronic disc displacement (often ADDwoR) may not present with anterior space widening, directly accounting for a portion of our false-negative cases. This heterogeneity in imaging presentation across disease stages, combined with the non-specific nature of the finding, collectively underpins the dual performance profile (high NPV, low PPV) we have quantified.

4.4 Impact of Gender and Age on Radiological Abnormalities

Multivariate analysis revealed a key finding: gender is an independent and significant factor influencing TMJ radiological abnormalities. Whether using CBCT-detected anterior joint space widening (*OR* = 0.668, $p = .044$) or MRI-confirmed anterior disc displacement (the gold standard) (*OR* = 0.390, $p < .001$) as the outcome measure, females exhibited a significantly higher risk of abnormalities compared to males.

Furthermore, our data reveals a critical interaction between gender and diagnostic performance and confirms the epidemiological characteristic from a radiological perspective. While females are more prone to true ADD, the PPV of CBCT is significantly higher in females (46.7%) compared to males (24.7%). This suggests a "Gender Paradox": although females have a higher disease burden, CBCT is more likely to provide a correct positive diagnosis in this group. Conversely, male patients, despite having a lower prevalence of the disease, suffer from a disproportionately high rate of false-positive diagnoses on CBCT. This implies that the anatomical variations in male joints are more frequently misinterpreted as pathological widening.

Notably, when using the gold standard MRI as the outcome, the statistical significance of the gender difference was stronger ($p < .001$). This suggests that the disparity between females and males in terms of actual disc position abnormalities is more pronounced than what is indicated by the indirect signs on CBCT. This finding is consistent with previous studies[8], which indicate that females not only have a higher true risk of disc displacement but also exhibit more prominent radiological manifestations.

This observed gender disparity may be mechanistically linked to inherent anatomical differences[22], with females presenting structural characteristics of the TMJ (e.g., thicker anterior articular disc bands and shorter mediolateral condylar dimensions[23]) that could compromise joint stability and predispose to disc displacement and associated anterior joint space widening and fluctuations in hormone levels[24]. Our results show that MRI-confirmed ADD is more prevalent in females, and the positive PPV of anterior

space widening on CBCT is significantly higher in females (46.7%) than in males (24.7%). This quantitative difference means that a positive CBCT finding in a male patient is more likely to be a false positive. Therefore, while MRI confirmation is required for all positive CBCT scans, this need is even more compelling in male patients due to the lower predictive value of the sign.

In contrast, age had no significant impact on either CBCT-detected anterior joint space widening or MRI-confirmed anterior disc displacement in our cohort ($p > .05$, see Table 4). The most plausible explanation for this null finding is the relatively homogeneous and young age distribution of our sample (15–60 years, predominantly young adults with a median age of 24.0 years), which may limit the detection of age-related effects and the generalizability of this result to older populations. Furthermore, the statistical robustness of this finding is supported by the use of non-parametric methods appropriate for the non-normal age distribution (Shapiro-Wilk test, $p < .001$), with age data reported as median and IQR to accurately reflect its central tendency and dispersion.

Additionally, the study may have been underpowered to detect subtle age-related effects or interactions between age and gender due to the limited sample size within specific age strata. It may also suggest that in the adult population studied, ADD is influenced more by intrinsic factors such as gender than by cumulative age effects. Multiple large-scale epidemiological studies have confirmed that the prevalence of ADD in adults aged 20–50 does not rise significantly with age; instead, degenerative changes such as osteoarthritis and osteophyte formation become more common with advancing age, rather than disc displacement itself[25].

4.5 Clinical Implications and Recommendations

Based on the findings above, we propose a gender-informed, imaging-based clinical decision pathway to optimize the diagnosis and management of patients with suspected TMD (see Fig. 5). The pathway leverages the high NPV of CBCT for efficient screening while emphasizing the necessity of MRI for confirmation and subtyping.

This pathway synthesizes the diagnostic performance metrics from this study. A normal anterior joint space on CBCT reliably excludes ADD (high NPV). A widened space necessitates MRI for confirmation due to a low PPV, which is even lower in male patients. Critically, CBCT cannot differentiate between ADD with and without reduction (ADDwR / ADDwoR); additionally, the two ADD subtypes (ADDwR and ADDwoR) were numerically close in this study, with no statistically significant difference in their prevalence, further supporting that CBCT cannot reliably distinguish between them, thus MRI is essential for both diagnosis and therapeutic subtyping.

1. Leverage the High NPV of CBCT for Screening: CBCT demonstrates high value in ruling out ADD due to its high NPV, making it an effective tool for preliminary screening. Therefore, in patients with suspected TMD, a normal anterior joint space on CBCT can essentially rule out ADD.

2. Interpret Positive CBCT Findings with Caution:

Due to the low PPV, a widened anterior joint space on CBCT should not be interpreted as a definitive diagnosis of ADD. Instead, this finding should serve as an indication to proceed with MRI for confirmation.

3. Recognize the Limitations in Subtyping and Gender-Specific Interpretation:

Given that CBCT cannot reliably distinguish between ADDwR and ADDwoR (as evidenced by its low PPV for ADDwoR alone), and considering the significantly lower PPV in male patients, MRI confirmation is essential before proceeding with any treatment plan that hinges on disc position or reducibility, particularly surgical intervention.

4. Standardize Radiological Reporting: Given the high false-positive rate of CBCT, radiological reports should avoid definitively diagnosing "anterior disc displacement" based solely on CBCT findings. Instead, use descriptive language such as: "Widening of the anterior joint space observed; further MRI evaluation is recommended to assess disc position." This approach prevents overtreatment, and reduces unnecessary patient anxiety.

4.6 Strengths and Limitations of This Study

The strengths of this study are primarily reflected in four aspects:

Rigorous Design with MRI as the Gold Standard: By employing strict inclusion and exclusion criteria to control for confounding factors such as joint degeneration, trauma, and occlusal relationships, and using MRI as the reference standard, the study design is robust, ensuring high reliability of the conclusions.

Quantification of Diagnostic Probability: This is the first study to explicitly propose the probability of diagnosing ADD based on anterior joint space widening observed on CBCT. While previous studies established an association between the imaging sign and disc displacement or investigated its morphological correlates[8,20,21], they did not quantify its diagnostic predictive values for clinical use. Our study provides critical evidence-based data by identifying a high NPV (94.4%) and a low PPV (39.9%). This offers a key foundation for standardizing imaging diagnostic pathways for TMD.

Large Sample Size Enabling Comprehensive Analysis: With 485 TMJs (from 282 patients) included, the sample size is substantial enough to conduct gender subgroup analyses, sensitivity analyses, and multivariate logistic regression. This allows for a systematic revelation of CBCT's diagnostic performance and influencing factors, resulting in stable findings with high clinical reference value.

Identification of Gender as an Independent Factor: Subgroup analysis revealed that gender is an independent factor influencing both CBCT diagnostic efficacy and the risk of ADD. Specifically, the PPV for females was significantly higher than for males (46.7% vs. 24.7%, $p < .001$), and the risk of ADD in females was 2.56 times higher than in males ($OR = 1/0.390 \approx 2.56$). These findings provide imaging

evidence for gender differences in TMD and support the implementation of gender-stratified management strategies in clinical practice.

However, this study also has certain limitations:

Single-Center Retrospective Design: The retrospective nature and single-center setting may introduce selection bias. However, the use of strict inclusion and exclusion criteria has minimized the impact of confounding factors to the greatest extent, ensuring the conclusions remain representative.

Qualitative Assessment of Joint Space: The evaluation of anterior joint space widening on CBCT relied on visual qualitative assessment rather than objective quantitative standards. Nevertheless, independent interpretation by two experienced physicians helped ensure a degree of result reliability. Future studies could adopt fused CBCT or quantitative measurement techniques[26] to enhance the accuracy of TMJ structural evaluation.

Age Distribution Bias: The study population consisted predominantly of young adults, with 70.9% aged 18–29 years (18–19 years: 38 cases; 20–29 years: 229 cases) and the overall age range of 15–60 years, which may limit the detection of age-related effects. However, this distribution aligns with the demographic characteristics of the high-risk population for TMD, meaning the results hold direct guidance significance for young TMD patients.

5. Conclusion

Anterior joint space widening observed on CBCT for diagnosing ADD is characterized by high sensitivity and high negative predictive value, but low specificity and low positive predictive value. Consequently, CBCT is highly suitable for the screening and exclusion of ADD, demonstrating high reliability in ruling out disc displacement, but it should not be used alone as a basis for definitive diagnosis.

Furthermore, females exhibit a significantly higher risk of both anterior joint space widening and ADD compared to males. Importantly, the positive predictive value of the sign is lower in males than in females, necessitating greater caution in interpreting positive CBCT findings in this group. Therefore, clinical applications must fully account for gender factors and implement stratified diagnostic and treatment strategies.

Declarations

Acknowledgement

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Data Availability

This retrospective study was reviewed and approved by the Institutional Review Board of the participating medical center (Approval No.: KQEC-2026-019-01). The requirement for informed consent was waived due to the retrospective design and the use of fully anonymized imaging data. The data sets used and analyzed in this study can be provided by correspondents according to reasonable requirements.

Authors' Contributions

Conceptualization, D.Z. and S.H.; Methodology, D.Z. and S.H.; Investigation, Z.C., C.L., Z.W., Y.L., M.C., M.J., and G.L.; Data curation, Z.C., C.L., and Z.W.; Formal analysis, Z.C., C.L., and Z.W.; Project administration, Y.Z.; Writing–original draft, Z.C.; Writing–review & editing, D.Z. and S.H.; Supervision, D.Z. and S.H. All authors have read and agreed to the published version of the manuscript.

Ethical Statement and Conflicts of Interest

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Ethics Committee/Institutional Review Board of the Hospital of Stomatology, Sun Yat-sen University (Approval No.: KQEC-2026-019-01). Due to the retrospective nature of the study and the use of fully anonymized imaging data, the requirement for informed consent was waived by the same ethics committee.

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References

1. List T, Jensen RH. Temporomandibular disorders: old ideas and new concepts. Cephalalgia. 2017;37(7):692–704.
2. Lazarin RO, Previdelli ITS, Silva RdosS, Iwaki LCV, Grossmann E, Filho LI. Correlation of gender and age with magnetic resonance imaging findings in patients with arthrogenic temporomandibular disorders: a cross-sectional study. Int J Oral Maxillofac Surg. 2016;45(10):1222–8.
3. Whyte AM, McNamara D, Rosenberg I, Whyte AW. Magnetic resonance imaging in the evaluation of temporomandibular joint disc displacement: a review of 144 cases. Int J Oral Maxillofac Surg. 2006;35(8):696–703.
4. Min CK, Jung W, Joo S. Enhanced multistage deep learning for diagnosing anterior disc displacement in the temporomandibular joint using MRI. Dentomaxillofac Radiol. 2024;53(7):488–96.

5. Schiffman EL, Look JO, Hodges JS, et al. Randomized effectiveness study of four therapeutic strategies for TMJ closed lock. J Dent Res. 2007;86(1):58–63.
6. Aiken A, Bouloux G, Hudgins P. MR imaging of the temporomandibular joint. Magn Reson Imaging Clin N Am. 2012;20(3):397–412.
7. Morales H, Cornelius R. Imaging approach to temporomandibular joint disorders. Clin Neuroradiol. 2016;26(1):5–22.
8. Osama A, Musa M, Zhang HJ, et al. Cone-beam computed tomography as a diagnostic tool for TMJ morphological alterations in disc displacement. Int Dent J. 2025;75(5):100908.
9. Yu W, Jeon HH, Kim S, Dayo A, Mupparapu M, Boucher NS. Correlation between TMJ space alteration and disc displacement: a retrospective CBCT and MRI study. Diagnostics (Basel). 2023;14(1):44.
10. Larheim TA, Abrahamsson AK, Kristensen M, Arvidsson LZ. Temporomandibular joint diagnostics using CBCT. Dentomaxillofac Radiol. 2015;44(1):20140235.
11. La Rosa GRM, Loreto C, Pedullà E, Lombardo C. Association between estrogen receptors polymorphisms and temporomandibular joint disorders: A systematic review. Arch Oral Biol. 2025;170:106130.
12. Alqhtani NR, Alkhaldi MS, Alanazi AF, et al. Temporomandibular joint space dimensions among Saudi patients with temporomandibular disorders: MRI-based retrospective study. Int J Clin Pract. 2022;2022:5846255.
13. Lin Z, Zhou C, Hu Z, et al. Expert consensus on imaging diagnosis and analysis of early correction of childhood malocclusion. Int J Oral Sci. 2025;17(1):21.
14. Stimmer H, Grill F, Goetz C, et al. Lesions of the lateral pterygoid muscle: an overestimated reason for temporomandibular dysfunction: a 3T magnetic resonance imaging study. Int J Oral Maxillofac Surg. 2020;49(12):1611–7.
15. Çamlıdağ İ, Sayıt AT, Elmalı M. Is condyle morphology a factor for anterior temporomandibular disc displacement? Turk J Med Sci. 2022;52(5):1609–15.
16. Abrahamsson C. Masticatory function and temporomandibular disorders in patients with dentofacial deformities. Swed Dent J Suppl. 2013;231:9–85.
17. Manfredini D. Etiopathogenesis of disk displacement of the temporomandibular joint: a review of the mechanisms. Indian J Dent Res. 2009;20(2):212–21.
18. Pérez del Palomar A, Doblaré M. Influence of unilateral disc displacement on the stress response of the temporomandibular joint discs during opening and mastication. J Anat. 2007;211(4):453–63.
19. Liu X, Li CX, Gong ZC, Ma YY, Tuersun S. A three-dimensional imaging study of the effect of anterior disc displacement on the bony structural relationship of the temporomandibular joint [in Chinese]. Zhonghua Kou Qiang Yi Xue Za Zhi. 2024;59(2):157–64.
20. Zhou L, Tao K, Ma J, Pan X, Zhang K, Feng J. Relationship between temporomandibular joint space and articular disc displacement. BMC Oral Health. 2025;25(1):611.

21. Etöz M, Çabuk DS, Kütük N, Ercan I. Association between articular eminence structure and joint spaces in temporomandibular joints with anterior disc displacement. Niger J Clin Pract. 2024;27(3):408–14.
22. Luo D, Qiu C, Zhou R, Yu W, Li X, Yang J. MRI-based observation of the size and morphology of temporomandibular joint articular disc and condyle in young asymptomatic adults. Dentomaxillofac Radiol. 2022;51(3):20210272.
23. Hill CN, Coombs MC, Cisewski SE, et al. Structure-function relationships of TMJ lateral capsule-ligament complex. J Biomech. 2022;130:110889.
24. Zieliński G, Pająk-Zielińska B. Association between estrogen levels and temporomandibular disorders: an updated systematic review. Int J Mol Sci. 2024;25(18):9867.
25. Wu Z, Lin Y, Lin Y. Impact of age on degenerative joint disease of the temporomandibular joint: a systematic review and meta-analysis. Med (Baltim). 2025;104(17):e41915.
26. Feng JL, Ma RH, Sun LL, Zhao JR, Zhao YP, Li G. Quantitative assessment of condylar bone resorption using fused CBCT images: differentiating and diagnosing three distinct groups based on volume and thickness decrease. Dentomaxillofac Radiol. 2023;52(8):20230337.

Figures

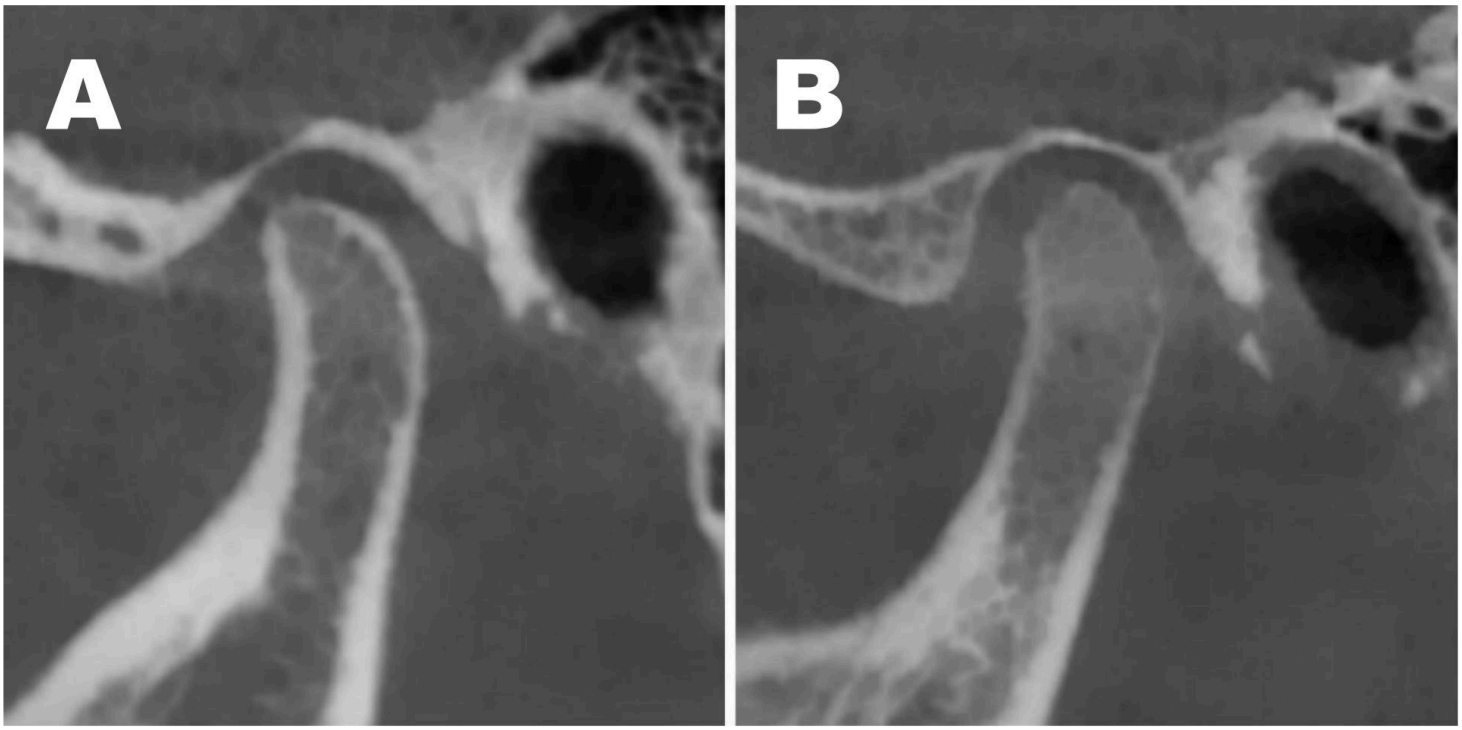


Figure 1

Oblique sagittal CBCT image of TMJ (closed position)

A: Normal joint space, upper space > posterior space > anterior space; B: Widened anterior joint space (anterior space > posterior space)

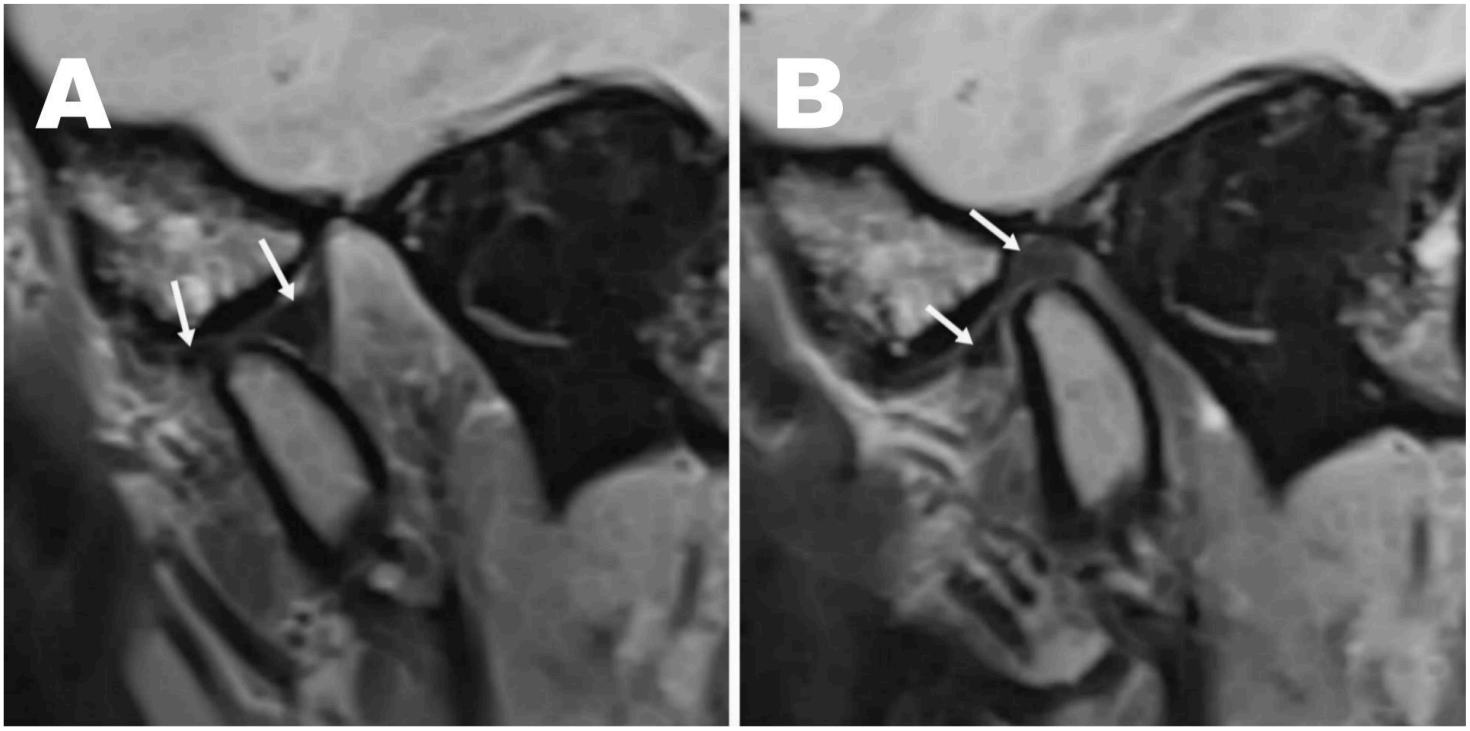


Figure 2

MRI images of normal TMJ disc-condylar position relationship

A: Closed position (the lower arrow indicates the anterior band of the articular disc, the upper arrow indicates the posterior band of the articular disc, and the thickest part of the posterior band is aligned with the transverse ridge of the condyle); B: Opening position (the left arrow indicates the anterior band of the articular disc, the right arrow indicates the posterior band of the articular disc, and the intermediate band is aligned with the transverse ridge of the condyle)

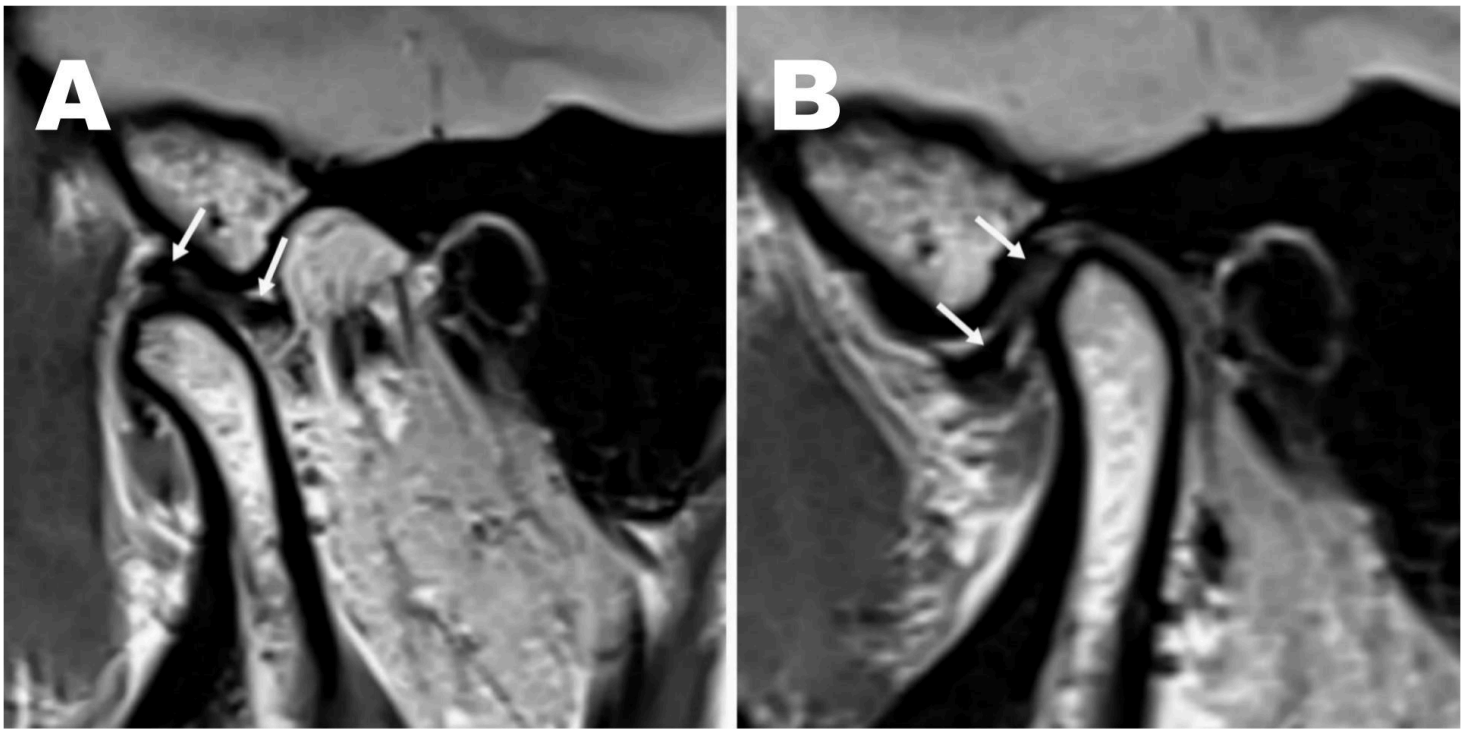


Figure 3

MRI images of anterior disc displacement with reduction

A: Closed position (the lower arrow indicates the anterior band of the articular disc, and the upper arrow indicates that the thickest part of the posterior band of the articular disc is located in front of the transverse ridge of the condyle); B: Opening position (the left arrow indicates the anterior band of the articular disc, the right arrow indicates the posterior band of the articular disc, and the middle band is facing the transverse ridge of the condyle)

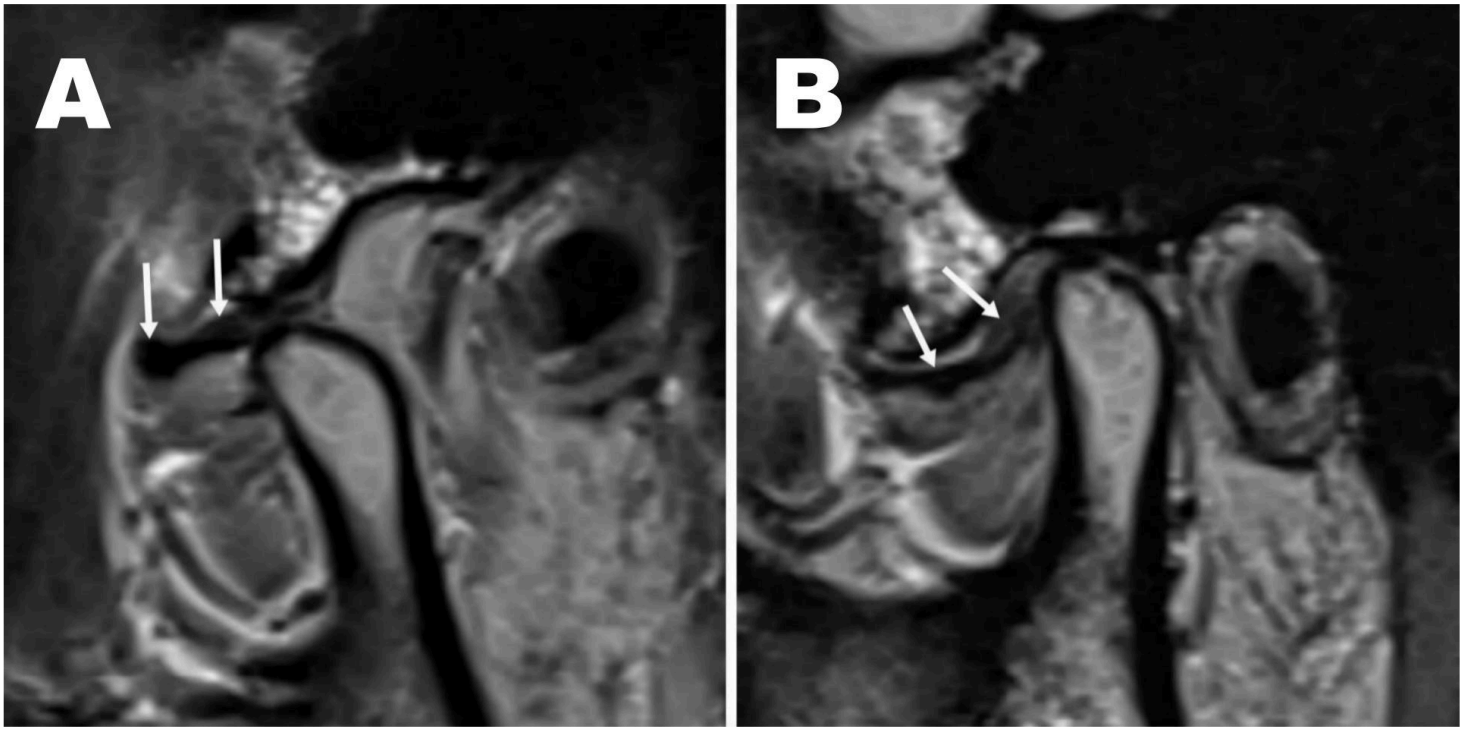


Figure 4

MRI images of anterior disc displacement without reduction

A: Closed position (the lower arrow indicates the anterior band of the articular disc, the upper arrow indicates the posterior band of the articular disc, and the thickest part of the posterior band is located at the anterior and lower edge of the condyle); B: Opening position (the left arrow indicates the anterior band of the articular disc, the right arrow indicates that the posterior band of the articular disc is located in front of the condyle, and the articular disc is deformed)

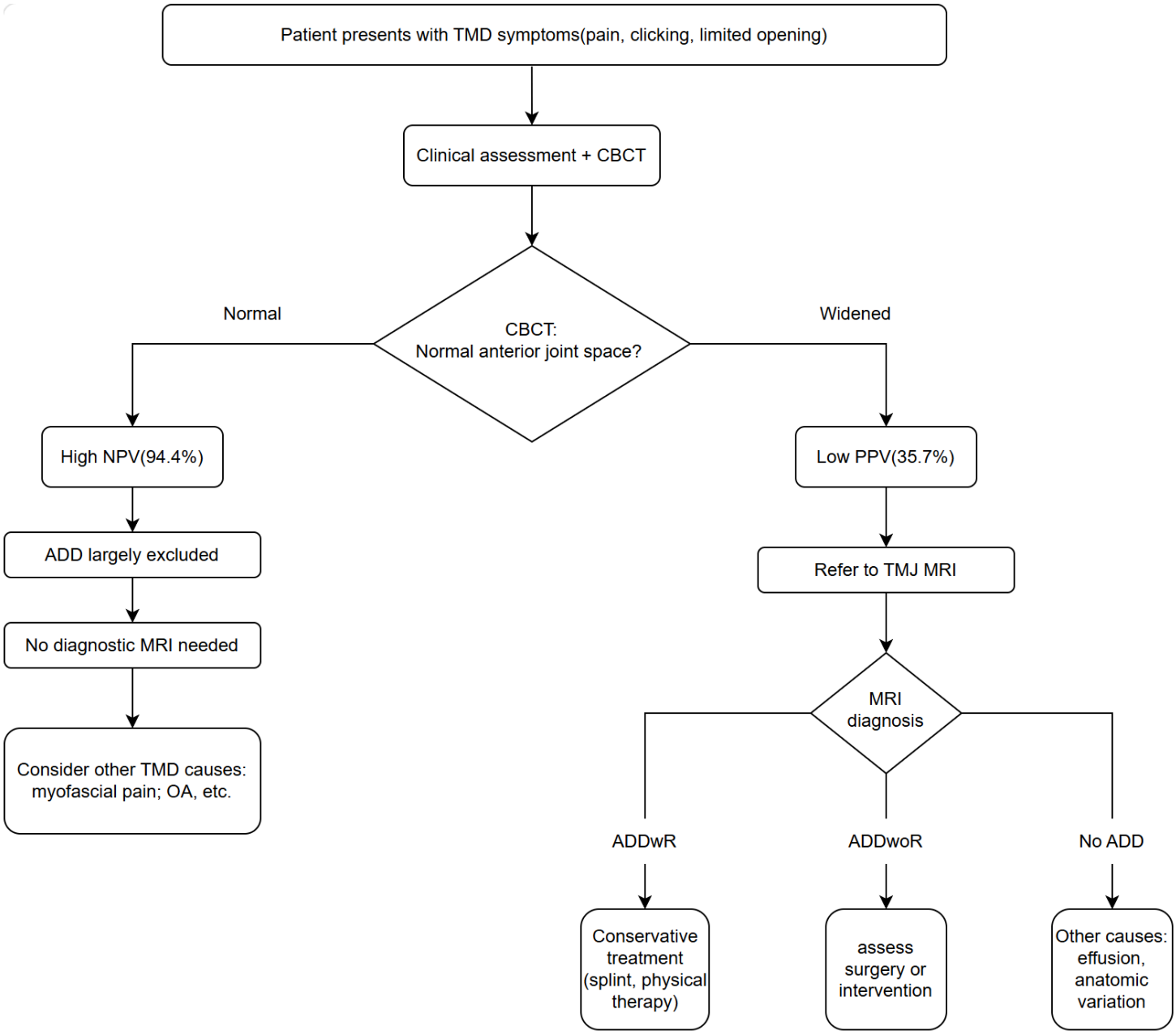


Figure 5

Evidence-based clinical imaging pathway for suspected ADD

This pathway synthesizes the diagnostic performance metrics from this study. A normal anterior joint space on CBCT reliably excludes ADD (high NPV). A widened space necessitates MRI for confirmation due to a low PPV, which is even lower in male patients. Critically, CBCT cannot differentiate between ADD with and without reduction (ADDwR / ADDwoR); additionally, the two ADD subtypes (ADDwR and ADDwoR) were numerically close in this study, with no statistically significant difference in their prevalence, further supporting that CBCT cannot reliably distinguish between them, thus MRI is essential for both diagnosis and therapeutic subtyping.