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REVIEW

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Temporomandibular disorder prevalence in malocclusion patients: a meta-analysis

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Abstract

Objectives This study investigated the prevalence of temporomandibular disorders (TMD) in patients with malocclusion through a systematic review and meta-analysis.

Materials and methods A comprehensive literature search was conducted up to November 15, 2024. Cross-sectional studies providing data on TMD prevalence among malocclusion patients were included. Study quality was assessed using the Joanna Briggs Institute (JBI) checklist. A random-effects model was used for meta-analysis, with subgroup and meta-regression analyses to explore heterogeneity. Sensitivity analyses were performed to evaluate result robustness.

Results Thirty-two studies were included, showing an overall TMD prevalence of 43% (95% CI: 35%-50%; I^2 = 97.9%). Prevalence was higher in females (44%) than males (33%) and in adults (42%) than adolescents (39%). Among malocclusion types, Class II (40%) and posterior unilateral crossbite (59%) had the highest TMD prevalence. Sensitivity analysis confirmed the robustness of findings, though diagnostic criteria variations contributed to heterogeneity.

Conclusions The prevalence of TMD in malocclusion patients was 43%, with higher rates in females, adults, and specific malocclusion types such as Class II, open bite, overjet, and crossbite. Variations in diagnostic criteria and malocclusion classification contributed to heterogeneity, emphasizing the need to consider individual patient characteristics when assessing TMD risk. Standardized diagnostic criteria, representative sampling, and multilingual search strategies are essential for future research to minimize bias and improve data reliability.

Keywords Malocclusion, Temporomandibular disorder, Prevalence, Meta-analysis

Introduction

Malocclusion, a globally prevalent oral health issue, affects around 48%–81% of the population [1, 2]. It is mainly caused by genetic and environmental factors during growth and development, and it can also result from trauma, periodontal disease, and other reasons after the completion of growth and development. The main symptoms of malocclusion are abnormal occlusion (such as irregular dentition, excessively wide or narrow interdental spaces, crowded dentition) and/or craniofacial disorders [2, 3]. In addition, malocclusion can affect dentofacial development and oral health/function [4–7], and specific malocclusion classes may be associated with temporomandibular disorders (TMD) [8, 9].

Currently, numerous orthodontists, especially maxillofacial surgeons, encounter various issues related to TMD when diagnosing and treating patients with malocclusion, such as TMD [10–13]. Understanding the TMD prevalence in patients with malocclusion can help orthodontists and maxillofacial surgeons accurately identify high-risk patients, develop personalized treatment plans, and take active management measures, thus significantly

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improving the quality of life of patients. Yap et al. found that two-thirds of the patients seeking orthodontic treatment exhibit symptoms related to TMD, with 20.3% of them experiencing moderate to severe TMDs [14]. Jain et al. reported that among individuals aged 19 to 30 years, approximately 24% of the patients with Class I and Class II malocclusion as well as 50% of the patients with Class III malocclusion were affected by some degree of TMD [15]. Conti's study reported that TMD was identified in 34% of the samples from the Department of Orthodontics, while moderate TMD was found in 3.5% [16]. In addition, a variety of similar studies have reported different prevalence rates of TMD [15, 17–19]. Therefore, a consensus on the prevalence of TMD among individuals with malocclusion has yet to be established.

Based on some original studies published to date, this study aimed to investigate the prevalence of TMD among individuals with malocclusion. The findings are intended to guide future studies and potentially contribute to developing guidelines and clinical management strategies.

Methods

The protocol of this meta-analysis was developed following the Preferred Reporting Project for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews. In addition, this study was registered in the International Prospective Register of Systematic Reviews (PROSPERO), identified by the registration number CRD42024518150.

Search strategy

This systematic review and meta-analysis aimed to address the following research question: What is the prevalence of TMD in patients with malocclusion, and how does this prevalence vary according to different diagnostic criteria, age groups, sex, and malocclusion subtypes? A comprehensive literature search on PubMed, Cochrane Library, EMBASE, and Web of Science electronic databases was conducted with no restrictions on region until 15 November 2024. The search terms were related to "prevalence", "malocclusion" and "temporomandibular disorder". The search strategies across various databases were nearly consistent. A supplementary manual search for grey literature was conducted through Google Scholar, university documents, and reference lists of other included studies. Specific search strategies are available in the supplementary material (Table S1).

Inclusion and exclusion criteria

Studies published in English and met the following criteria were included: (1) studies with data on the prevalence of TMD in malocclusion populations; (2) studies enrolled participants of all ages and sex diagnosed with all types of malocclusions, without restrictions on race or region; (3) articles with accessible full text; and (4) studies with a cross-sectional design.

Exclusion criteria were as follows: (1) duplicate publications; (2) reviews, systematic reviews, meta-analyses; (3) meeting abstracts/summaries, case reports, guidelines, letters to the editor, editorials, study protocols, brief communications, animal experiments; and (5) studies with non-extractable outcome data.

Literature screening

All retrieved studies were imported into EndNote X9 to eliminate duplicate records. Two investigators (Lijun, Huang (L, H) and Yafen, Xu (Y, X)) independently examined titles and abstracts to exclude articles that did not report the prevalence of TMD in malocclusion or were not suitable for calculating data. The results were cross-checked to ensure validity and accuracy. Disagreements between the two regarding study inclusion were resolved through discussions with a third investigator (Ziyi, Xiao (Z, X)).

Data extraction

The following data from eligible studies were collected: basic information (first author, country, year of publication), demographic and epidemiological information (sample size of patients with malocclusion, sample size of TMD patients among malocclusion patients, mean or median age, sample source), classification of malocclusions, diagnostic criteria for TMD. The data extraction process was completed by one investigator and independently reviewed by another. If there was any uncertainty or disagreement, a third independent investigator (Z, X) was consulted to resolve the issue.

Risk of bias and quality assessment

The risk of bias and methodological quality of the included studies were assessed using the Joanna Briggs Institute (JBI) checklist. This tool is specifically designed for systematic reviews and meta-analyses that report prevalence data, as described by the methodological working group of the Joanna Briggs Institute [20]. The checklist evaluates multiple aspects of the study design, including sampling methods, data collection methods, and statistical analyses to ensure its suitability for the current analysis. The JBI quality assessment tool for prevalence studies includes nine items [21], and each item was judged as 'yes,' 'no,' 'unclear,' or 'not applicable.' Based on the scores, each study was rated as high quality (≥7), moderate quality (5–6), or low quality (≤4) [21–23]. To identify the potential sources of bias, three key factors were particularly evaluated, including sample selection, diagnostic criteria, and data reporting. The quality assessment was independently carried out by two investigators (L, H and Y, X), and any disagreements were tackled by a third investigator (Z, X).

Statistical analysis

STATA software (version 16.0, StataCorp LLC, College Station, Texas, USA) was employed to conduct data analysis. Heterogeneity between the included studies was assessed using the Cochran chi-square test and then quantified by the I^2 value. Studies were categorized as low heterogeneity ($I^2 < 25\%$), moderate heterogeneity ($I^2 = 25–75\%$), and high heterogeneity ($I^2 > 75\%$). Heterogeneity was considered present among the corresponding studies when $p < 0.1$ or $I^2 > 50\%$ [24]. A random-effects model was utilized if there was significant heterogeneity between studies. Otherwise, a fixed-effects model was chosen. To explore the sources of heterogeneity, subgroup analyses and meta-regression analyses with a random-effects model were performed to assess the prevalence of TMD in patients with malocclusion based on sex, age, and subtypes of malocclusion. To evaluate the impact of study quality and individual studies on the pooled results, sensitivity analyses were performed through the leave-one-out method, with each study sequentially removed to observe its influence on the overall effect size. Additionally, a restricted sensitivity analysis was conducted, in which only high-quality studies (low risk of bias) were included. Then the pooled effect size from these studies was compared to the original pooled estimate to assess the robustness of the findings. All statistical analysis results were deemed significant at a threshold of $p < 0.05$.

Results

Search results

A sum of 1367 studies were located. Subsequently, 442 duplicate articles, 89 review papers, and 110 publications (e.g. animal experiments, non-English literature, conference abstracts, and case reports) were excluded. Moreover, 669 of the remaining 726 studies were excluded following reading the title and abstract. After reviewing the remaining 48 articles that potentially met the criteria, 16 studies were further excluded. Among them, ten studies were not cross-sectional studies, five studies did not include individuals with malocclusion, and one study reported the same data as another study. Table S2 lists the articles excluded after the full-text review. Ultimately, 32 studies were included in the meta-analysis. The specific screening process can be found in Fig. 1.

Characteristics of the included studies

The studies included were published from 2002 to 2024. According to geographic location, most studies were conducted in Europe ($n = 18$), followed by South America ($n = 9$), and Asia ($n = 5$). Moreover, 16 of the included studies were conducted at schools/institutes/villages/recruits, 9 at clinics, and 5 at the orthodontics department. The sample sizes of the main studies ranged from 19 to 7,476. All selected studies used a cross-sectional study design. Twenty studies enrolled participants under the age of 20, nine included participants aged between 20 and 40, and three encompassed participants across all age ranges. TMD was diagnosed based on Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) (Axis I and Axis II) in 8 studies, Axis I of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) in 4 studies, Fonseca Anamnestic Index (FAI) in 6 studies, and Helkimo Index in 4 studies. In the remaining 11 studies, TMD was diagnosed with a specific interview combined with clinical examination (Table 1).

Quality assessment of the selected studies

Research quality was evaluated in accordance with the JBI Critical Appraisal Tool. Seventeen studies were classified as high-quality, while 14 studies were considered moderate quality and only one was rated as low quality (Table S3).

The bias identified in the included studies was mainly due to sample selection, diagnostic criteria, and data reporting. Many studies relied on convenience sampling, such as recruiting participants from orthodontic clinics or schools, which may limit the generalizability of the findings to the wider populations. Variability in the diagnostic criteria for TMD, including self-reported questionnaires and clinical examinations using different tools (e.g., DC/TMD, Helkimo Index) also contributed to heterogeneity and potential misclassification. Furthermore, some studies had incomplete or inconsistent reporting of demographic data, such as age and sex distributions, limiting the ability to perform more detailed subgroup analyses.

Systematic review and meta-analysis

A total of 18 studies reported the prevalence rate of TMD. The total sample size was 11,348, among which 3,492 were diagnosed with TMD. Our systematic review showed a range of TMD prevalence of 15.6%–78.9%. Meta-analysis revealed that the overall prevalence of TMD in malocclusion was 43% (95% CI: 35% 50%; $I^2 = 97.9\%$) (Fig. 2).

Subgroup analysis

To explore the sources of heterogeneity, a subgroup analysis was conducted based on TMD diagnostic criteria, sex, age, and subtypes of malocclusion (Table 2). Subgroup analyses showed varying TMD prevalence

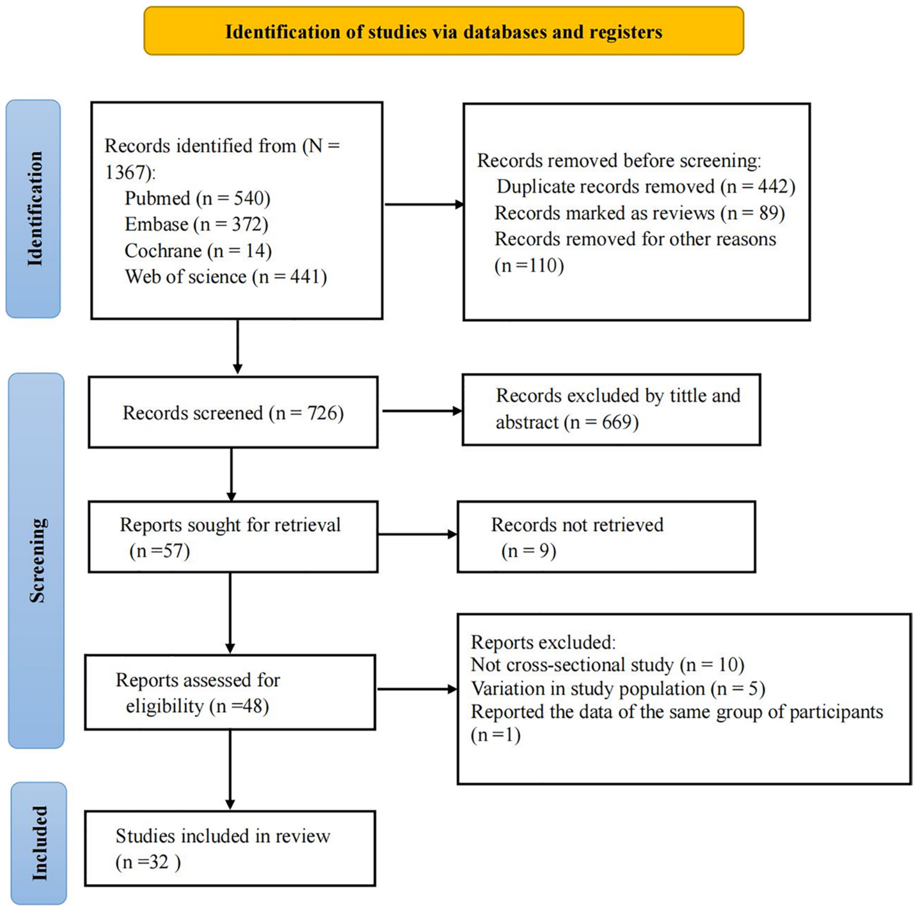

Fig. 1 PRISMA flow diagram for search and selection of eligible studies included in the meta-analysis

across diagnostic criteria, with Helkinmo Anamnestic Index at the highest rate of 49% (95% CI: 23%–75%), followed by DC/TMD at 47% (95%CI: 38%–57%), and FAI at 46% (95%CI: 24%–67%). RDC/TMD Axis I, however, identified the lowest prevalence of TMD at 30% (95%CI: 18%–43%).

For the age-based subgroup analysis, the prevalence of TMD in participants aged < 19 years (39%, 95% CI: 20%–57%) was lower than that in participants aged ≥ 19 years (42%, 95% CI: 28%–56%).

In the sex subgroup, the prevalence of TMD was higher in females (44%, 95% CI: 24%–64%) than in males (33%, 95% CI: 22%–44%).

For the subgroup analysis on malocclusion subtypes, the prevalence of TMD was highest in patients with Class II malocclusion (40%, 95% CI: 32%–49%), followed by Class III (39%, 95% CI: 27%–50%). Prevalence of TMD was lowest in Class I malocclusion (31%, 95% CI: 24%–38%). Within the Class II subclassifications, the prevalence of TMD in Class II/2 (44%, 95% CI:23%–64%) was higher than in Class II/1 (39%, 95% CI:28%–49%). For other malocclusion subtypes, the TMD prevalence rate for open bite, overjet, and crossbite were 42% (95% CI: 24%–59%), 40% (95% CI: 36%–44%), and 37% (95% CI: 27%–48%), respectively. Moreover, in crossbite subclassifications, the prevalence of TMD was highest in posterior unilateral crossbite (59%, 95% CI: 46%–72%), followed by posterior crossbite (30%, 95% CI: 15%–45%), and anterior crossbite (18%, 95% CI: 8%–28%).

Meta-regression

Meta-regression showed that different Class categories may be the source of heterogeneity ($P = 0.048 < 0.05$).

Sensitivity analysis

Sensitivity analysis of TMD prevalence in the total malocclusion population suggested that none of the studies exerted a significant influence on the overall results (Table S4). Sensitivity analysis of high-quality studies (low risk of bias) showed a pooled effect size of 0.35 (95% CI: 0.26, 0.44), lower than the original 0.43 (95% CI: 0.35, 0.50), suggesting that studies with higher bias may

Table 1 General characteristics of the included studies

Author	Year	Continent	Country	Age (years)	Events(TMD diagnosis in malocclusion)	Total(No. of patients with malocclusion)	Diagnostic criteria of TMD	Classification of malocclusion	Outcome(in malocclusion)	Setting	Study type
Alpaydin	2024	Europe	Turkey	14.82 ± 2.06	NR	NR	Clinical examination: at least one sign/symptom	Angle Class I, Angle Class II, Angle Class III, Anterior crossbite, Posterior crossbite	NR	Department of Orthodontics of Ordu University	cross-sectional
Torul	2024	Europe	Turkey	10.03 ± 1.88, 5–15	14	65	FAI	NR	NR	the Oral and Maxillofacial Surgery Clinic of Ordu University	cross-sectional
Karaman	2022	Europe	Turkey	14–19	364	648	DC/TMD (Axis I and Axis II)	Class I, Class II, Class III	gender	the Orthodontics Department	cross-sectional
Baldiotti	2022	South America	Brazil	13–18	32	59	RDC / TMD(Axis I and Axis II)	No (DAI ≤ 25),Yes (DAI ≥ 26)	NR	a university's dental clinic	cross-sectional
Macrì	2022	Europe	Italy	10.9 ± 2.1	99	411	Axis I of the DC/TMD	NR	NR	Chieti and Murcia Clinic for orthodontic advice	cross-sectional
Wu	2021	Asia	China	18–19	92	277	Axis I of the DC/TMD	Angle's malocclusion, Anterior teeth overbite, Anterior teeth overjet, Posterior teeth crossbite, Posterior scissor bite	NR	Zhuhai campus of Zunyi Medical University	cross-sectional
Yap	2021	Asia	Singapore	21.02 ± 5.45	92	138	FAI	NR	age,gender	the orthodontic clinic of a national dental center	cross-sectional
Berar	2020	Europe	Romania	20–25	24	28	interviewed + clinical examination	Angle class II division 2	gender	the Faculty of Dentistry	cross-sectional
Taneja	2019	Asia	India	12–15	NR	NR	clinical examination and Questionnaire(FAI)	over bite,over jet,open bite, cross bite, class	age,gender	secondary schools	cross-sectional
Tecco	2019	Europe	Italy	15.09 ± 1.9	250	567	DC/TMD	Class I, Class II/1, Class II/2, Class III, Left and right different class	age,gender	a dental university clinic	cross-sectional
Jain	2018	Asia	India	12–30	88	390	FAI	Class I, Class II, Class III	age,gender	Government College of Dentistry	cross-sectional

Table 1 (continued)

Author	Year	Continent	Country	Age (years)	Events(TMD diagnosis in malocclusion)	Total(No. of patients with malocclusion)	Diagnostic criteria of TMD	Classification of malocclusion	Outcome(in malocclusion)	Setting	Study type
Valinhas	2018	Europe	Portugal	13.0 ± 0.72	72	139	FAI	Class I, Class II, Class III	NR	two Portuguese schools	cross-sectional
Elumalai	2018	South America	Brazil	10–14	179	489	RDC/TMD Axis I	over bite,over jet,open bite, cross bite, class	age,gender,Anxiety level	public and private schools	cross-sectional
Bilgiç	2017	Europe	Turkey	7–12	无	无	Modified Helkimo Dysfunction Index	Class I, Class II/1, Class II/2, Class III, bimaxiller protrusion, overjet,overbite, posterior crossbite	gender	three different central schools	cross-sectional
Yalçın	2017	Europe	Turkey	21.26 ± 2.15	209	321	FAI	sagittal, vertical, transverse, vertical + sagittal, vertical + transverse, sagittal + transverse	NR	Department of Oral and Maxillofacial Radiology of the Faculty of Dentistry	cross-sectional
Svedström-Oristo	2016	Europe	Finland	18–61	35	50	using a semi-structured diary	NR	NR	two university clinics	cross-sectional
Piao	2016	Asia	Korea	all ages	1,773	7,476	defined as the presence of pain, limited mouth opening, and/or an audible sound heard on joint movement	Skeletal Class I, Skeletal Class II, Skeletal Class III	age	Department of Orthodontics	cross-sectional
Sousa	2015	South America	Brazil	34.76 ± 13.47	27	79	RDC/TMD	anterior open bite, posterior crossbite, overjet, overbite, posterior teeth	NR	Family Health Units (FHUs)	cross-sectional
Marangoni	2014	South America	Brazil	7–12	15	19	Helkimo index, RDC/TMD Axis I	Open bite, Posterior crossbite, Mixed	NR	the Rogationist Institute	cross-sectional
Ballanti	2013	Europe	Italy	6–16	NR	NR	RDC/TMD	Class I, Class II, Class III, crossbite, functional deviation	NR	null	cross-sectional
Lauriti	2013	South America	Brazil	15.64 ± 1.06	NR	NR	Helkimo Index	Class I, Class II, Class III, open bite,crossbite;	age,gender,facial pattern,breathing pattern,parafunctional habits	Education Institute	cross-sectional
Kawala	2011	Europe	Poland	21.2 ± 1.6	40	174	Helkimo Anamnestic Index	NR	gender	army recruits	cross-sectional

Table 1 (continued)

Author	Year	Continent	Country	Age (years)	Events(TMD diagnosis in malocclusion)	Total(No. of patients with malocclusion)	Diagnostic criteria of TMD	Classification of malocclusion	Outcome(in malocclusion)	Setting	Study type
Tecco	2011	Europe	Italy	5–15	NR	NR	RDC/TMD	Cl I, Cl II/1, Cl II/2, Cl III	NR	the University	cross-sectional
Pereira	2010	South America	Brazil	12	NR	NR	RDC/TMD	Class I, Class II, Class III, open bite, deepbite, crowding	gender,menarche,diastemas,mouth-breathing,Atypical swallowing,Labial sealing,Lip Interposition,Finger thumb-sucking	schools	cross-sectional
Pereira	2009	South America	Brazil	4–12	NR	NR	at least one sign or symptom	Class (II or III), open bite, deepbite, crowding	NR	Pediatric Dentistry Clinic	cross-sectional
Tecco	2010	Europe	Italy	5–15	NR	NR	RDC/TMD	Anterior crossbite, Posterior bilateral crossbite, Posterior unilateral crossbite	NR	NR	cross-sectional
Bonjardim	2009	South America	Brazil	18–25	97	193	Helkimo's anamnestic index	Class I, Class II, Class III	NR	Tiradentes University	cross-sectional
Godoy	2007	South America	Brazil	16–18	61	390	questionnaire of TMD, a clinical TMD examination	anterior open bite, posterior crossbite	NR	schools	cross-sectional
Marklund	2007	Europe	Sweden	23 ± 4.9	NR	NR	Case history + Clinical examination	crossbite, deep bite, open bite, overjet	NR	University	cross-sectional
Gesch	2004	Europe	Germany	20–81	NR	NR	the TMD diagnosis guidelines of the Academy of Orofacial Pain	Open bite, overje, Scissors-bite unilateral	NR	towns and villages	cross-sectional
Thilander	2002	Europe	Sweden	5–17	NR	NR	Clinical examination and registrations	Angle Class I, Angle Class II, Angle Class III, bimaxillary protrusi on,overjet,overbite, posterior crossbite	NR	the Dental Health Service	cross-sectional
ɷelić	2002	Europe	Croatia	19–28	45	100	Clinical Functional Examination + Questionnaire	Angle Class I, Angle Class II/1, Angle Class II/2, Angle Class III, Cross bite	NR	male recruits	cross-sectional

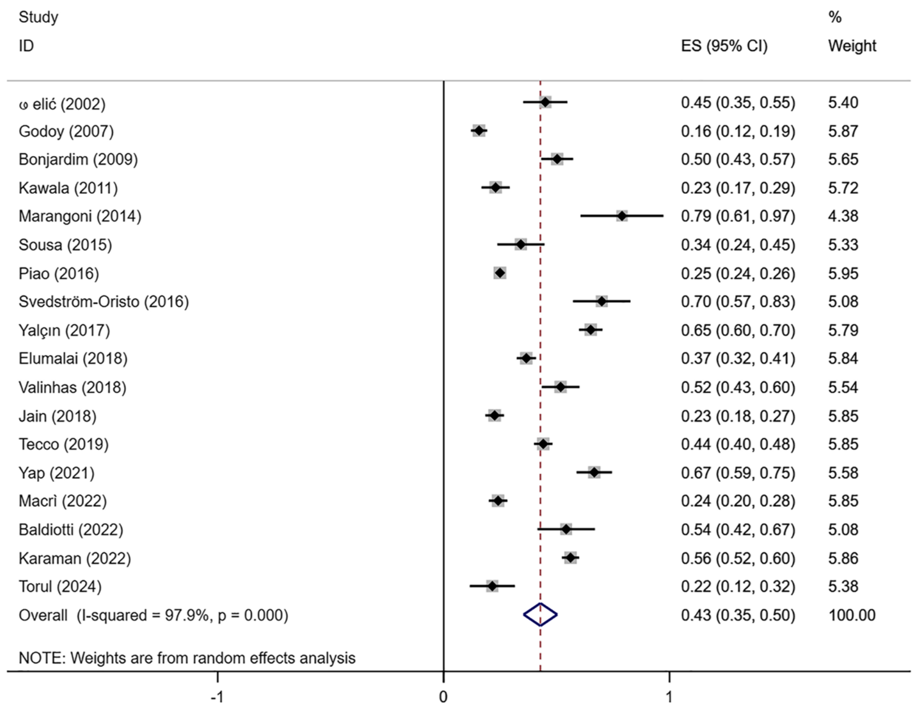

Fig. 2 Forest plot of prevalence of TMD in malocclusion patients

overestimate TMD prevalence. Excluding high-quality studies one by one did not significantly alter the pooled effect size, confirming the robustness of the findings (Table S5).

Discussion

This study introduced the first meta-analysis of TMD prevalence in patients with malocclusion and showed that the overall prevalence of TMD in the malocclusion population was 43% (95% CI: 35%–50%). Although the prevalence of TMD varied according to diagnostic methods, with the highest prevalence found in patients diagnosed by the Helkinmo Anamnestic Index (49%, 95% CI: 23%–75%), the overlapping CIs suggested that these differences were not statistically significant. Similarly, while subgroup analyses revealed differences in TMD prevalence across age, sex, and malocclusion types, caution should be exercised when interpreting these findings given the exploratory results and imprecise data. For instance, the prevalence of TMD was slightly higher in participants aged ≥ 19 years (42%, 95% CI: 28%–56%) than in those aged < 19 years (39%, 95% CI: 20%–57%), and higher in women than in men. Among malocclusion classifications, Class II showed the highest prevalence (40%), with Class II/2 (44%) being higher than Class II/1. Open bite exhibited the highest prevalence (42%) among other malocclusion types, and posterior unilateral crossbite topped the list among crossbite subtypes (59%). These trends, however, need to be further validated with larger and more precise datasets in future studies. Of the 32 studies included, only one was of low quality, accounting for 3%, so the overall study quality was good.

The bias in the included studies mainly came from sample selection, diagnostic criteria, and inconsistent reporting. Many studies relied on convenience sampling, with most participants from specific settings (such as orthodontic clinics or schools), which limited the generalizability of the findings to the wider population. In addition, heterogeneity in TMD diagnostic criteria (from self-reported questionnaires to clinical examinations using different tools, such as DC/TMD, Helkimo index) may lead to classification bias and increase heterogeneity in outcomes. Some studies had incomplete or inconsistent reporting of demographic data, such as age and sex distributions, which further limited the ability to conduct detailed subgroup analyses. These biases reflect the exploratory nature of subgroup analyses and caution is advised in interpreting the results. To improve the reliability and comparability of research results, future studies should adopt standardized diagnostic criteria and representative sampling methods.

The sensitivity analysis conducted for TMD prevalence in the total malocclusion population suggested that no single study significantly influenced the overall results, confirming the robustness of the findings. When restricted to studies with a low risk of bias (high-quality

Table 2 The pooled overall prevalence of TMD in study subgroups

Subgroup	Numbers of studies	Numbers of TMD in malocclusions	Sample size	Subgroup analysis				Meta-regression	
				prevalence	95% CI	I^2 (%)	*p*-value	I^2 (%)	*p*-value
Malocclusion	18	3492	11348	0.43	0.35, 0.50	97.90%	0.000		
Criteria for diagnosing TMD								0.00%	0.094
DC/TMD	4	673	1353	0.47	0.38, 0.57	89.00%	0.000		
RDC/TMD Axis I	2	278	900	0.30	0.18, 0.43	94.10%	0.000		
FAI	5	475	1053	0.46	0.24, 0.67	98.20%	0.000		
Helkinmo Anamnestic Index	3	152	386	0.49	0.23, 0.75	96.20%	0.000		
Others	4	1914	7656	0.37	0.25, 0.49	96.70%	0.000		
Age	9	2277	8357	0.40	0.28, 0.51	99.10%	0.000	0.00%	0.984
< 19	6	820	4293	0.39	0.20, 0.57	98.80%	0.000		
≧19	3	1457	4064	0.42	0.28, 0.56	96.10%	0.000		
Sex	17	1152	3679	0.38	0.28, 0.49	98.80%	0.000	0.00%	0.635
Males	9	452	1789	0.33	0.22, 0.44	97.20%	0.000		
Females	8	700	1890	0.44	0.24, 0.64	99.30%	0.000		
Class classification of malocclusion				0.36	0.32, 0.40	96.80%	0.000	0.00%	0.048
Class I	15	2009	7334	0.31	0.24, 0.38	97.80%	0.000		
Class II	21	934	3187	0.40	0.32, 0.49	97.10%	0.000		
Class II/1	6	393	1179	0.39	0.28, 0.49	90.70%	0.000		
Class II/2	6	145	439	0.44	0.23, 0.64	94.50%	0.000		
Class III	14	315	998	0.39	0.27, 0.50	94.70%	0.000		
Different classes on both side	3	129	426	0.34	0.15, 0.53	93.70%	0.000		
Other classification of malocclusion				0.37	0.32, 0.43	94.80%	0.000	0.00%	0.067
Bimaxiillary protrusion	2	192	626	0.29	0.23, 0.36	65.10%	0.090		
Crowding	3	60	578	0.17	0.00, 0.34	92.70%	0.000		
Open bite	9	59	186	0.42	0.24, 0.59	86.60%	0.000		
Overbite	7	286	961	0.34	0.17, 0.51	97.30%	0.000		
Overjet	7	274	684	0.40	0.36, 0.44	0.00%	0.481		
Crossbite	17	209	776	0.37	0.27, 0.48	92.20%	0.000		
Anterior crossbite	4	63	351	0.18	0.08, 0.28	82.10%	0.001		
Posterior crossbite	7	67	269	0.30	0.15, 0.45	83.50%	0.000		
Posterior unilateral crossbite	2	32	54	0.59	0.46, 0.72	0.00%	0.806		

studies), the pooled effect size was 0.35 (95% CI: 0.26, 0.44), which was lower than the original effect size of 0.43 (95% CI: 0.35, 0.50). This result indicates that studies with a higher risk of bias may have slightly overestimated the prevalence of TMD. These results highlight the need for future studies to adopt rigorous methodologies to minimize potential bias and enhance the reliability of prevalence estimates.

In this systematic review, we summarized the range of TMD prevalence across studies (15.6%–78.9%) and found that the wide variation in prevalence may be influenced by sample sources, diagnostic tools, and study designs. The results of the meta-analysis showed that the overall prevalence of TMD in patients with malocclusion was 43% (95% CI: 35%–50%). This result lies near the middle of the prevalence range in the systematic review, supporting the conclusion of previous studies that TMD has a certain prevalence (21.1%–73.3%) in the malocclusion population [9]. Meanwhile, the meta-analysis further revealed that malocclusion type may be a source of heterogeneity in the risk of TMD by quantifying the prevalence in different subgroups (e.g., sex, age, malocclusion type, and diagnostic tools).

By summarizing experimental occlusal interference studies published over 68 years, Clark et al. [25] found that contacts disrupting maximum intercuspation can hinder the seamless functioning of the jaw and, in some instances, lead to muscular discomfort and joint clicking. Mediotrusive interferences may result in tensile loads in the temporomandibular joint (TMJ) complex, and occlusal treatments, such as prosthetics and orthodontics, may challenge or even exceed the adaptability of TMJ [26, 27]. Nonetheless, there are studies in the systematic review that point out that the direct causal relationship between malocclusion and TMD is unclear, especially in studies that did not adequately control for confounders. The results of the meta-analysis similarly had significant heterogeneity ($I^2 = 98.1\%$), suggesting that differences in sample selection, diagnostic tools, and study quality may have led to inconsistent results. Thus, by combining the qualitative insights of systematic reviews with the quantitative validation of meta-analysis, this study both reveals the limitations of the current evidence and provides a clearer direction for future research.

The current study showed that the lowest prevalence of TMD was observed in patients diagnosed by RDC/TMD Axis I, at 30%. However, a higher TMD prevalence rate was found in patients diagnosed by, Helkinmo Anamnestic Index, DC/TMD, and FAI at, 49%, 47%, and 46% respectively. The Helkinmo Anamnestic Index categorizes patients that have three affirmative responses to perceived problems (headache, neck pain, and emotional stress) as having mild TMD with low sensitivity [28], resulting in a high prevalence of diagnosed TMD. FAI is a quick and easy-to-use tool that consists of 10 questions and does not require clinical examination [29, 30], which may account for the higher prevalence of TMD in patients with malocclusion. RDC/TMD protocol can be divided into two axes: Axis I is used to measure symptoms and signs by memory questionnaire and clinical examination [31–33]. Axis II is used to assess the psychological state and pain-related disability of TMD [34]. As a subset of the RDC/TMD diagnostic criteria, Axis I is characterized by a more rigorous diagnostic standard that typically results in a lower estimated prevalence rate. The above evidence firmly supports our findings.

This study found that the prevalence of TMD among adolescents with malocclusion was lower than that of adults. Adolescents are at a critical stage of growth, and their TMJs show greater adaptability and plasticity than adults [35, 36]. This enhanced adaptability may help to reduce the prevalence of TMD in adolescents. A systematic review reported that the overall prevalence of TMJ disorders was higher in adults (approximately 31%) than in children and adolescents (11%) [37]. Additionally, a meta-analysis found that the global incidence of TMDs was 34%, with the population of 18–60 years being the most affected, further supporting the higher prevalence in adults [38]. Together, these results suggest that age may be a key factor in the pathogenesis of TMD. The present study further found that age also significantly affected the risk of TMD in the malocclusion population. Moreover, the results showed that TMD affected female patients with malocclusion more frequently, which is consistent with the findings of a previous study [39]. Studies have demonstrated that sex plays a significant role in the development of TMD. It has been reported that women have twice the risk of TMD than men [39]. Genome-wide association study has revealed that muscle RAS oncogene homolog (MRAS) may contribute to reducing the incidence of painful TMD in males, and this is a male-specific effect [40]. This finding supports our results that women have a higher prevalence of TMD than men. Sex-specific disparities in estrogen signaling predispose women to a higher risk of developing TMD. Moreover, the distinct anatomical and structural features of the TMJ in men and women may result in biomechanical alterations, and thus mechanical fatigue is more likely to occur in women [41]. A case–control study [42] suggested that in women with TMD, estrogen might trigger a hyperinflammatory response, potentially leading to increased clinical pain through central sensitization. This reminds clinicians to pay special attention to the symptoms of female patients with malocclusion when diagnosing and treating TMD and to consider the possible impact of sex differences on the treatment effect.

At the same time, the prevalence of TMD in Class II was higher than that in Class III and Class I. The prevalence of TMD was higher than that in open bite, overjet, and crossbite than that in other types (overbite, bimaxiillary protrusion, crowding) of malocclusion. These results suggest that certain specific types of malocclusion may increase the risk of TMD, which has important implications for clinical evaluation and treatment planning. Evidence [43] showed altered TMJ morphology in Class II vertical and Class II horizontal patients. In addition, MRI evaluation demonstrated a tendency for anteromedial disc displacement and anteriorly positioned condyles in Class II vertical patients. Moreover, Ari-Demirkaya A et al. found that open bite cases exhibit greater vertical discrepancies between centric relation and centric occlusion slides, along with shorter protrusion paths than normal cases. However, in asymptomatic and symptomatic TMD patients, statistically significant differences between centric relation and maximum intercuspation at the condylar level were quantifiable [44]. One study [45] reported that children with posterior crossbite may experience decreased bite force during chewing or occlusion, due to asymmetric muscle function. The anterior temporalis muscle was more engaged on the side of the crossbite, whereas the masseter muscle exhibited reduced activity on the same side. This finding implied that crossbites could play a significant role in the development of myogenous TMD. Therefore, in the process of examination and diagnosis of patients seeking orthodontic treatment, clinicians should pay more attention to the state of TMJ in patients with class II, open bite, and crossbite malocclusion, and find out the possible TMD in time. Articles have demonstrated that patients with osteoarthrosis are often characterized by longer retruded contact position-intercuspal position occlusal slides and larger overjet [46]. Children and adolescents with overjet deviations of > 6 mm in comparison to the norm are associated with significant limitations of the oral health-related quality of life [47]. However, we were unable to determine whether certain high-risk occlusal features are risk factors for TMD or whether occlusal problems may be secondary to TMD. In any case, our results have important implications for clinical practice. The initial evaluation and dynamic monitoring of TMJ function should be enhanced during orthodontic treatment of high-risk malocclusion types for TMD (e.g., class II malocclusion, open bite).

Limitations

However, this meta-analysis had several limitations. First, variations in TMD diagnostic criteria and malocclusion classifications across studies introduced classification bias and contributed to heterogeneity, limiting direct comparisons. Although subgroup analyses were performed, inconsistencies in definitions prevented standardized evaluations. Second, many studies relied on convenience sampling (e.g., orthodontic clinics or schools), reducing the generalizability of findings. Additionally, incomplete demographic data reporting (e.g., age and sex) hindered more detailed subgroup analyses. Third, only English-language studies were included, which may have introduced language bias and excluded relevant non-English research. Lastly, high heterogeneity (I^2 = 97.9%) suggests substantial variability in sample selection, diagnostic tools, and study designs. While sensitivity analyses indicated that study quality had minimal impact on the pooled estimates, potential bias cannot be entirely ruled out. Future research should prioritize standardized diagnostic criteria, representative sampling methods, and multilingual search strategies to improve reliability and generalizability.

Conclusion

This meta-analysis found that the overall prevalence of temporomandibular disorders (TMD) in malocclusion patients was 43%, with higher prevalence in females, adults, and certain malocclusion types such as Class II and posterior unilateral crossbite. Sensitivity analysis confirmed the robustness of results, though variations in diagnostic criteria and study quality contributed to heterogeneity. These results suggested that we should pay close attention to the possible risk of TMD in orthodontic clinical settings. Future studies should prioritize standardized diagnostic criteria, representative sampling methods, and multilingual search strategies to minimize bias and enhance the generalizability of findings.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13005-025-00490-0.

Supplementary Material 1: Table S1. Search strategy. Table S2. The list of the articles excluded after the full-text review. Table S3. Detail data from JBI quality assessment. Table S4. The forest plots for the sensitivity analysis. Table S5. The forest plots for the restricted sensitivity analysis (studies with a low risk of bias).

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Not applicable.

Authors' contributions
All authors contributed to the study conception and design. Writing—original draft preparation: L.H.; Writing—review and editing: L.H.; Conceptualization: Y.X.; Methodology: Y.X.; Formal analysis and investigation: Z.X.; Funding acquisition: F.L.; Resources: Y.L.; Supervision: F.L., and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was a review and meta-analysis of existing, published literature not requiring ethics committee approval.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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