

# Correlations Between Mandibular Asymmetries and Temporomandibular Disorders: A Systematic Review

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Received : 18-04-21  
Revised : 09-05-21  
Accepted : 13-05-21  
Published : 03-07-21

ABSTRACT

**Objective:** This systematic review aimed to investigate the correlation between mandibular asymmetry and temporomandibular disorders (TMDs). **Materials and Methods:** A systematic search of the published literature was performed in electronic databases such as PubMed (MEDLINE), Scopus, Web of Science, Cochrane, Google Scholar, Clinicaltrials.gov, and Saudi Digital Library. Gray literature was searched through System for Information on Grey Literature through OpenGrey. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was followed in the investigation. The focussed question according to PICO format was: “does the mandibular asymmetry contribute to temporomandibular disorders”? Eligibility criteria included clinical trials (CTs), observation studies, cross-sectional and cohort studies in English that investigated mandibular asymmetries and TMD among patients. Blind and duplicate study selection, data extraction, and risk of bias assessment were carried out. **Results:** The initial search resulted in 1906 articles, of which 11 (8 CTs, 1 cross-sectional, 1 retrospective, and 1 observational) studies were selected for qualitative synthesis after fulfilling the eligibility criteria. **Conclusion:** Most of the studies included in this review showed either very high risk or high risk of bias. Despite the low certainty of evidence, the current study indicated a likely relationship between mandibular asymmetries and TMDs.

**KEYWORDS:** Asymmetry, mandibular asymmetry, temporomandibular disorder

## INTRODUCTION

Asymmetry in the craniofacial region was first described in 1887 by an artist Hasse. His Greek statutory investigation showed that sculptors were created with mild-to-moderate asymmetries with greater mandibular length on the left side.<sup>[1]</sup> The prevalence of mandibular discrepancy is more common on the left side (82%) than on the right side (47.5%).<sup>[2]</sup> Asymmetries of the mandible lead to aesthetic issues and functional problems due to their significant role in the stomatognathic system. Ultimately it ends up in an imbalanced occlusion, problems of masticatory muscles, and temporomandibular joint (TMJ) problems.<sup>[3,4]</sup> There was no independent association

observed between mandibular asymmetry and age, sex, or absence of posterior teeth. However, mandibular asymmetry was found to correlate with individuals' sagittal jaw relationship.<sup>[5]</sup>

Most of the studies measured asymmetries based on gnathion and menton displacement relative to the midsagittal plane since the mandible is considered a primary structure leading to dentofacial

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**How to cite this article:** Alqhtani N, Alshammery D, AlOtaibi N, AlZamil F, Allaboon A, AlTuwaijri D, et al. Correlations between mandibular asymmetries and temporomandibular disorders: A systematic review. J Int Soc Prevent Communit Dent 2021;11:481-9.

Access this article online	
<b>Quick Response Code:</b> 	<b>Website:</b> www.jispcd.org
	<b>DOI:</b> 10.4103/jispcd.JISPCD_130_21

asymmetry.<sup>[4,6-9]</sup> Furthermore, condylar asymmetries are believed to be among the most potent causes of mandibulofacial asymmetries.<sup>[10-12]</sup> Studies have shown that if asymmetries are not treated in growing patients, mandibular displacement can change the amount and severity of force applied to both the mandible and TMJ.<sup>[13,14]</sup>

Temporomandibular disorders (TMDs) were introduced to orthodontics based on Thompson's theories. It was observed that malocclusion would cause displacement of the posterior and superior condyle. As the TMJ is bilateral, any asymmetry might alter the balance and cause microtrauma.<sup>[15,16]</sup>

TMDs include various clinical problems of masticatory muscles, the TMJ, and the associated structures.<sup>[17]</sup> They are considered one of the leading causes of pain of non-dental origin in the orofacial region affecting at least 50% of the general population. Pain is an unpleasant emotional and sensorial experience correlated with actual or potential harm. The muscular nature of pain was reported in more than two-thirds of the cases (76%), and joint pain was observed in 26% of the cases.<sup>[18,19]</sup>

Costen recognized a relationship between occlusion and TMJ for the first time. He was also the first to realize the signs and symptoms of TMD in 1934.<sup>[20]</sup> The etiology of TMD is multifactorial rather than a single anatomical or functional disharmony. It could be due to dysfunctions of masticatory musculature, changes in TMJ structure, malpositioning or loss of teeth, postural changes, or a combination of several factors. It is produced mainly by psycho-emotional or peripheral factors such as occlusal disharmony that can trigger TMD. Vertical asymmetry of the condyle and the ramus are associated with articular surfaces predisposing to TMD.<sup>[16,18,21]</sup>

Various imaging techniques are applied to assess the TMJ, such as tomography, computed tomography (CT), transcranial radiography, arthrography, and magnetic resonance imaging (MRI).<sup>[22]</sup> The three-dimensional measurement approach is more reliable and effective in investigating the morphology of TMJ than the two-dimensional methods.<sup>[23]</sup> Surgical management for TMDs is very limited, and noisy joint without any pain or dysfunction does not require any intervention.<sup>[22-26]</sup> Patients with occlusal problems such as deep overbite, Class II division 2 malocclusion, and gross maxillomandibular disharmonies are at increased risk of developing TMDs than others.<sup>[25]</sup>

Multiple factors such as hormones, genes, bruxism, and psychosocial conditions are implicated in the TMDs.

Moreover, reported studies on the relationship between TMDs and dental occlusion are weak.<sup>[26,27]</sup> Hence, some experts continue to advocate rigorous review of TMD and dental occlusion.<sup>[28]</sup>

Previous studies have reported controversy between facial asymmetry and TMD.<sup>[29,30]</sup> However, still it remains unclear whether or not mandibular asymmetry affects the TMD.<sup>[23,24,31]</sup> With the inclusion of TMD in orthodontics and maxillofacial surgery, more research focussed on mandibular asymmetries to determine the role of skeletal morphology in developing TMJ dysfunctions.<sup>[9]</sup>

It is necessary to gather cumulative data to know whether asymmetric mandibular conditions constitute etiological or predisposing factors for the development of TMDs. Therefore, this systematic review aims to present information on the correlation between mandibular asymmetry and TMDs.

## MATERIALS AND METHODS

### SEARCH STRATEGY

The literature search was conducted on June 17, 2020, including all the articles before this date, using PubMed (MEDLINE), Scopus, Web of Science, Cochrane, Google Scholar, Clinicaltrials.gov, and Saudi Digital Library (SDL). Gray literature was searched through System for Information on Grey Literature through OpenGrey. Simultaneously, unpublished articles were searched through the SDL and Google Scholar search engine.

The search strategy included the controlled vocabulary MeSH terms (((Mandibular [MeSH Terms]) or (lower jaw [MeSH Terms])) AND (asymmetry [MeSH Terms])) AND (temporomandibular disorders [MeSH Terms]) OR (disorders, tmj [MeSH Terms])). The free keywords search included Asymmetry, TMD, temporomandibular disorder, mandibular asymmetry terms.

The question was framed following the PICO (population, intervention, comparison, and outcome) format. The focussed question according to the PICO format was: "does the mandibular asymmetry contribute to temporomandibular disorders?"<sup>[32]</sup>

- P (population): Patients with mandibular asymmetry
- I (intervention): No intervention
- C (comparison): Patients without asymmetry
- O (outcome): Temporomandibular disorder

This systematic review was designed as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols/guidelines.<sup>[33]</sup>

**INCLUSION AND EXCLUSION CRITERIA**

The studies of clinical trials (CTs), observational research, and cross-sectional and cohort studies published in the English language were included in the review without any limitation on patient’s age, race, gender, country, and publication date.

Publications involving non-human subjects or *in-vitro* studies, studies with data not reliably extracted, duplicate or overlapping data, articles with no full text available, case reports, case series, and other systematic reviews were excluded.

**STUDY SELECTION AND DATA EXTRACTION**

After reading the title and abstract of the relevant articles, the full text for the possible articles was screened for outcome variables. Two reviewers independently and blindly extracted information on research characteristics utilizing the customized data extraction form. Duplicated studies were identified and removed by using reference management software (EndNote™ X8 for Macintosh).

**ASSESSMENT OF RISK BIAS WITHIN STUDIES**

Observational studies were evaluated for risk of bias using the Newcastle–Ottawa scale. Every individual study was analyzed and categorized based on the protocol [Table 1]. Cohen’s kappa was used to measure the level of agreement between the two reviewers with the possible disagreements solved by an experienced orthodontist (third reviewer). The current systematic review was conducted without a grant from any funding agencies.

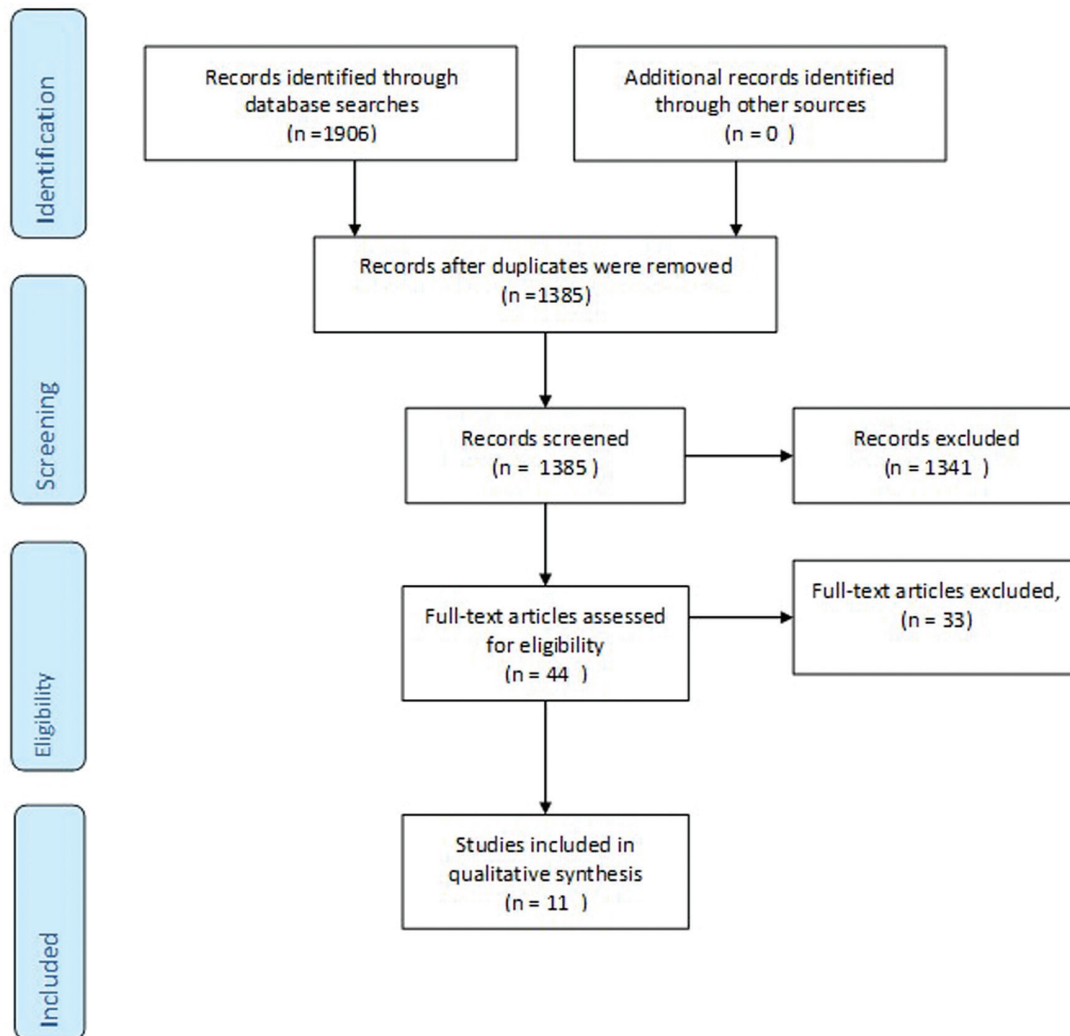
**RESULTS**

A flow diagram of the search and selection process of articles based on PRISMA guidelines is presented in Figure 1. The initial search retrieved 1108 articles from the SDL, 228 from Google Scholar, 33 from the Web of Science, 15 from Scopus, and 1 from clinicaltrial.gov. A total of 521 duplicates were identified and excluded from the review. The first phase included 1385 articles. After carefully reviewing titles and abstracts, studies with irrelevant aims and titles not applicable to our study were omitted, leaving 44 papers eligible for further analysis. After the full-text screening, 11 articles were considered for the final review. Eight CTs<sup>[9,31,34-38]</sup> and each of the cross-sectional,<sup>[39]</sup> retrospective,<sup>[40]</sup> and observational<sup>[41,42]</sup> studies fulfilled the review’s eligibility criteria [Table 2].

The studies included in the systematic review were published in different countries between 1995 and 2019. The sample size ranged from 16 to 174. Studies reported a wide range of age variations of the study

**Table 1: Study quality assessment using the Newcastle–Ottawa scale for case–control studies**

No.	References	Selection			Comparability of cohorts		Outcome		Total score
		Adequate case definition	Representativeness of cases	Selection of controls	Definition of controls	Ascertainment of exposure	The same method of ascertainment	Non-response rate	
1	Yáñez-Vico <i>et al.</i> <sup>[35]</sup>	*	*	*	*	*	*	*	6
2	Ooi <i>et al.</i> <sup>[38]</sup>	*	*	*	*	*	*	*	2
3	Noh and Lee <sup>[34]</sup>	*	*	*	*	*	*	*	5
4	Chung <i>et al.</i> <sup>[39]</sup>	*	*	*	*	*	*	*	4
5	Kawakami <i>et al.</i> <sup>[42]</sup>	*	*	*	*	*	*	*	4
6	Goto <i>et al.</i> <sup>[40]</sup>	*	*	*	*	*	*	*	7
7	Khojastepour <i>et al.</i> <sup>[41]</sup>	*	*	*	*	*	*	*	5
8	Endo <i>et al.</i> <sup>[37]</sup>	*	*	*	*	*	*	*	7
9	D’Ippolito <i>et al.</i> <sup>[9]</sup>	*	*	*	*	*	*	*	2
10	Raustia <i>et al.</i> <sup>[36]</sup>	*	*	*	*	*	*	*	7
11	de Leão <sup>[43]</sup>	*	*	*	*	*	*	*	2



**Figure 1:** PRISMA flow chart of the search strategy showing that the initial search retrieved from the selected database was 1910. After full-text screening, 11 articles were considered for the final review

participants. The lowest age was 14 years, and the highest reported age was 65 years. The TMJ diagnostic method differed across the studies reviewed: three studies performed MRI coupled with anteroposterior and lateral cephalometrics.<sup>[36,38,40]</sup> Two studies used 3D CT<sup>[37]</sup>; computed beam computed tomography (CBCT)<sup>[41]</sup> and CT<sup>[35,36]</sup> scans were used in two different studies. All other studies utilized panoramic and anteroposterior cephalograms to diagnose TMD.<sup>[39,42,43]</sup> In one study, anteroposterior cephalograms and hand tracing were performed on the images.<sup>[9]</sup>

In one study, the symmetric mandibular group is compared with mandibular (body, ramus, atypical, and C-shaped) asymmetries to TMD.<sup>[37]</sup> Other study compared among the right, left, and no deviations of the mandible while assessing TMD.<sup>[38,41]</sup> Three studies assessed the mandibular asymmetries between TMD and non-TMD patients.<sup>[33,39,41]</sup> One study compared

bruxism, headache, and difficulties in opening the mouth between TMD and healthy volunteers.<sup>[36]</sup>

D'Ippolito *et al.*<sup>[9]</sup> studied the mandibular asymmetry and temporomandibular abnormalities using posteroanterior cephalometric analysis of patients undergoing orthodontic treatment. It was found that orthodontic treatment resolved their TMD after the correction of mandibular asymmetry. However, their study's key drawback was the limited sample size ( $n = 16$ ), making it difficult to apply results at a larger scale.

Noh *et al.* used panoramic radiographs to study the relationship between mandibular asymmetry and TMDs in TMD and non-TMD patients. It was found that mandibular height by more than 4.37% increases the risk of TMD by 4.57-fold. The incidence of asymmetry was higher in the arthrosis group when compared with the non-arthrosis group.<sup>[33]</sup> Similar outcomes of

**Table 2: Reported studies on the investigation of the correlation between mandibular asymmetries and TMDs**

References	Participants	Intervention and control/ comparative group	Diagnostic method (CT or?)	Result	Author's conclusion
Yáñez-Vico <i>et al.</i> <sup>[35]</sup>	n=32, age 25–42 years	With and without TMD	CT	<ol style="list-style-type: none"> <li>1. Condyle width, length, and height measurement. No significant difference between the original and repeated measurement</li> <li>2. Width and length of condyle. No significant difference between the two groups</li> <li>3. The total height of the condyle process was less in the TMD group</li> </ol>	<ol style="list-style-type: none"> <li>1. The condylar asymmetries in the sagittal, vertical, and transversal plane may be related to TMD</li> <li>2. The most common feature of TMD patients was shorter condylar height compared with asymptomatic patients</li> </ol>
Ooi <i>et al.</i> <sup>[38]</sup>	n=75, age 15–45 years	ADDWR, bony changes	MRI, lateral cephalometric	In facial asymmetry patients, the prevalence of ADDwoR and bony changes were greater in the left side compared with the right side	Facial asymmetry is closely related to internal derangement of TMD
Noh and Lee <sup>[34]</sup>	n=100, age 30–60 years	TMD patients, non-TMD patients	OPG	<ol style="list-style-type: none"> <li>1. A significant difference in asymmetry incidence between control and TMD groups</li> <li>2. Incidence of asymmetry was not related to age and gender in both of the TMD and control groups.</li> <li>3. The incidence of neither muscle disorder nor disk displacement was related to the incidence of asymmetry</li> </ol>	Asymmetry of mandibular height by more than 4.37% increases the risk of TMD by 4.57-fold. It was associated with arthritic changes in TMD patients
Chung <i>et al.</i> <sup>[39]</sup>	n=174, age 25.7 years	Symmetric, 4 subdivided asymmetric groups. Group 1, mandibular body asymmetry; group 2, ramus asymmetry; group 3, atypical asymmetry; and group 4, C-shaped asymmetry	Anteroposterior cephalograms	<ol style="list-style-type: none"> <li>1. ENPP1 SNP-rs6569759 group 1</li> <li>2. rs858339 group 3</li> <li>3. ESR1 SNP-rs164321 group 4</li> <li>4. ESR1 SNP-rs3020318 associated with principal components 1 and 2</li> <li>5. The genes can be associated with atypical asymmetry, mandibular body asymmetry, and C-shaped asymmetry and TMD</li> <li>6. The study showed that orthodontic and orthognathic treatment of asymmetry will relieve TMD symptoms for at least 1 year</li> </ol>	There is a probability of association of TMD and genotypes
Kawakami <i>et al.</i> <sup>[42]</sup>	n=35, age 16–38 years	Right deviation, left deviation, no deviation	Anteroposterior cephalograms, MRI	<ol style="list-style-type: none"> <li>1. The deviated group showed steeper eminence on the TMJ compared with the non-deviated group</li> <li>2. On the deviated side, the anterior joint space was narrower than the non-deviated side</li> </ol>	The morphology of the TMJ in mandibular asymmetry with prognathism is different between right and left sides, which leads to facial asymmetry

Continued					
References	Participants	Intervention and control/ comparative group	Diagnostic method (CT or?)	Result	Author's conclusion
Goto <i>et al.</i> <sup>[40]</sup>	1. With mandible deviation: <i>n</i> =28, age 17–34 years 2. Control <i>n</i> =12, age 20–30 years	Mandibular deviation, no mandibular deviation orthognathic surgery	MRI	The deviated side of the TMJ showed smaller condyle and an increase in the incidence of disk displacement	The abnormal side may be associated with mandibular deviation
Khojastepour <i>et al.</i> <sup>[41]</sup>	<i>n</i> =42, age 18–65 years	Condyle asymmetry with TMD, non-TMD	CBCT	1. The measures of TMD patients according to CAI were significantly higher than non-TMD patients 2. The dysfunctional index was different within TMD patients, whereas the CIA was not 3. No correlation was found between age and CAI	1. Higher CAI in patients is more likely to develop TMD 2. The value of CAI is not a standard for the signs and symptoms of TMD
Endo <i>et al.</i> <sup>[37]</sup>	1. <i>n</i> =20, age 19–29 years 2. <i>n</i> =9, age 23–27 years	TMJ position of mandibular asymmetry and normal patient	3D CT	There is no significant difference in the condylar area. Mandibular asymmetry patients had larger fossas and longer condylar processes on the non-deviated side and narrower fossa-condyle interspaces on the deviated side, predominately in the posterolateral section of TMJ	The patients with mandibular asymmetry had a posterolateral rotation of the condyle within the fossa of the deviated side
D'Ippolito <i>et al.</i> <sup>[9]</sup>	<i>n</i> =16, age 14–36 years	Mandibular asymmetry orthodontic treatment	Anteroposterior cephalograms; hand tracing	TMD symptoms are completely relieved by treating mandibular asymmetries	Symmetries of the mandible can be a predisposing factor to TMD development
Raustia <i>et al.</i> <sup>[36]</sup>	<i>n</i> =77, age 15–33 years	TMD and/ or bruxism, headache, and difficulties in opening the mouth, compared with healthy volunteers	CT scan	The relation between occlusal interferences and TMD signs and symptoms is statistically significant	In asymmetrical patients, occlusal discrepancies may be a predisposing factor to TMD
de Leão <sup>[43]</sup>	<i>n</i> = 52, age 18–65 years	TMD patients	Panoramic radiographs, anteroposterior cephalograms	1. Statistically, there was no significant difference between sides with/without pain 2. The tendency was found for patients with unilateral pain to have larger measurement differences in the comparison of the two sides	Correlations were found between the cephalometric measurements on the two radiographic exams, but the measurements on the images did not demonstrate an association with the predominant side of pain

TMD = temporomandibular disorder, TMJ = temporomandibular joint, CT = computed tomography, ADDwoR = anterior disc displacement without reduction, MRI = magnetic resonance imaging, CBCT = computed beam computed tomography, CAI = condyle asymmetry index

mandibular asymmetry and TMD were reported by de Leão *et al.* based on the panoramic radiograph and posterioranterior cephalogram images of the patients.<sup>[43]</sup>

According to Khojastepour *et al.*,<sup>[41]</sup> TMD patients have a significantly higher condylar asymmetry than those of non-TMD, although there is no difference in various dysfunction indices within the TMD patients. Besides, no significant relationship between the condylar asymmetry index and age was reported in the study.

Yanez-Vico *et al.* showed that traditional radiographic approaches could diagnose craniofacial asymmetries, whereas 3-D methods provide a comprehensive diagnosis. The condylar height, length, and width were the commonly affected in TMD patients. Patients suffering from TMD showed shorter condylar height compared with asymptomatic individuals. Condylar asymmetry may be found in TMD patients as a result of the disturbance in the regular load applied to TMJ.<sup>[35]</sup>

Raustia *et al.* showed a significant correlation between the asymmetric occlusal variables (interference in bilateral canine guidance, dental midline asymmetry, deviation of the protrusion and lateral occlusal asymmetry, amount and lateral deviation of the retruded contact position, and intercuspal position slide) and the degree of TMD. Therefore, the TMD signs and symptoms were linked to asymmetrical occlusal interferences.<sup>[36]</sup> Endo *et al.* noted that the patient with mandibular asymmetry had larger fossa and longer condylar processes on the non-deviated side and narrower fossa-condylar interspaces on the deviated side, mainly in the posterolateral section of TMJ.<sup>[37]</sup>

Goto *et al.* examined the TMJ on the deviated and non-deviated sides in mandibular asymmetry patients clinically and radiographically using MRI. Findings suggested that TMJ on the deviated side had a higher incidence of anterior disk displacement and smaller condyle than the non-deviated side. No relation was found between disk displacement and clinical symptoms.<sup>[40]</sup> Whereas Ooi *et al.* found that bony changes and the anterior disc displacement without reduction (ADDwoR) were more frequently seen on the left side than on the right side.<sup>[38]</sup> Kawakami *et al.* studied the morphology of TMJ in mandibular asymmetry and prognathism patients. It was found that TMJ on the deviated side had a significantly steeper eminence and a narrower anterior joint space than that of the non-deviated side.<sup>[42]</sup> It was assumed that the genes could be associated with atypical asymmetry, mandibular body asymmetry, C-shaped asymmetry, and TMD. Chung *et al.* studied the impact of genes on

pre- and post-orthodontic and orthognathic patients with TMD and facial asymmetries. The study showed that orthodontic and orthognathic asymmetry therapy relieves TMD symptoms for at least 1 year.<sup>[39]</sup>

## DISCUSSION

This systematic review assessed the correlation between mandibular asymmetry and TMD by retrieving 11 studies. After scientific assessment and study quality assessment using the Newcastle–Ottawa scale, three studies were categorized as very high risk, five as high risk, and the last three were low risk, thus influencing the reliability of their relative results.<sup>[44]</sup> In Yanez-Vico *et al.*'s study, TMD cases showed statistically significant differences in mean condylar process height, which was lower in control cases. It contradicts the suggestion that asymmetry indices would be higher in patients suffering from TMDs, likely due to a rise in hard tissue thickening of the joint articular surface, resulting from increased loading on this surface.<sup>[35]</sup> Because of different methods, apparent differences are found in the asymmetry values of this study. These differences may be attributed to the age differences in the subjects with a negative age-to-vertical asymmetry relation. The use of 3D-CT reconstructions demonstrated the high accuracy of the measurement.

de Leão studied the accuracy of linear measurements on 3D-CT images and the physical measurements taken on skulls.<sup>[43]</sup> Moreover, inconsistencies in the results may be due to several imaging techniques utilized in these studies. The majority of the included studies used a traditional approach to diagnose asymmetry by taking posterioranterior cephalograms to assess asymmetry, although CBCT images were taken into consideration for more reliable asymmetric diagnosis.<sup>[45]</sup> Problems of malocclusion that affect oral function could lead to TMD and asymmetric growth of the mandible, thereby increasing the prevalence of TMD cases. Nevertheless, there is no way to tell if an increase in mandibular condyles height was a pathological or physiological process from the reviewed papers from this study. Future research is required on this subject.

## STRENGTHS AND LIMITATIONS

This systematic review included an extensive literature search using PRISMA strategy, which was utilized in retrieving the information on correlation between mandibular asymmetries and TMDs. Moreover, quality assessment of the studies was performed using the Newcastle–Ottawa scale.

We acknowledge some of the limitations in our study. Risk of bias of CTs with Cochrane Risk of Bias-2 scale

has not been considered in this study. Moreover, the Newcastle–Ottawa scale does not help to exclude all types of biases for all kinds of observational studies. Meta-analysis of the studies could have given much deeper insight into the correlation between TMD and asymmetric growth of the mandible.

## CONCLUSION

Most of the studies included in this review showed either very high risk or high risk of bias.

Despite the low certainty of evidence, the current study indicated a likely relationship between mandibular asymmetries and TMDs. Further studies of appropriate risk of bias assessment and meta-analysis are required to determine a stronger estimate relationship between mandibular asymmetries and TMDs.

## ACKNOWLEDGEMENTS

Not applicable.

## FINANCIAL SUPPORT AND SPONSORSHIP

Nil.

## CONFLICTS OF INTEREST

There are no conflicts of interest.

## AUTHORS CONTRIBUTIONS

Nasser Alqhtani: Concepts, design, literature search; Deema Alshammery: Concepts, design, data acquisition; Nawaf AlOtaibi: Literature search, data acquisition, manuscript preparation; Faisal AlZamil: Literature search, data acquisition, manuscript preparation; Aljowhara Allaboon: Literature search, manuscript preparation; Dana AlTuwaijri: Literature search, manuscript preparation; Mohammad Abdul Baseer: Manuscript preparation, manuscript editing, manuscript review.

## ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT

The study was registered at research center of Riyadh Elm University (SRS/2020/10/194/183). This study has been conducted in accordance with the World Medical Association Declaration of Helsinki.

## PATIENT DECLARATION OF CONSENT

Not applicable.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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