Systematic Review Article

Prevalence of mandibular asymmetry in different skeletal sagittal patterns: *A systematic review*

Karine Evangelista[a]; Ana Beatriz Teodoro[b]; Jonas Bianchi[c]; Lucia Helena Soares Cevidanes[d]; Antônio Carlos de Oliveira Ruellas[e]; Maria Alves Garcia Silva[f]; José Valladares-Neto[g]

ABSTRACT

Objectives: To analyze the prevalence of mandibular asymmetry in skeletal sagittal malocclusions.

Materials and Methods: PubMed/MEDLINE, EMBASE, LILACS, Web of Science, Scopus, LIVIVO and gray literature (OpenGrey, ProQuest, and Google Scholar) were electronically searched. Two independent investigators selected the eligible studies, and assessed risk of bias and certainty of evidence (GRADE). One reviewer independently extracted the data and the second reviewer checked this information. Any disagreement between the reviewers in each phase was resolved by discussion between them and/or involved a third reviewer for final decision.

Results: Electronic search identified 5,132 studies, and 5 observational studies were included. Risk of bias was low in two studies, moderate in one, and high in two. The studies showed high heterogeneity. Mandibular asymmetry ranged from 17.43% to 72.95% in overall samples. Horizontal chin deviation showed a prevalence of 17.66% to 55.6% asymmetry in Class I malocclusions, and 68.98% in vertical asymmetry index. In Class II patients, prevalence of mandibular asymmetry varied from 10% to 25.5% in horizontal chin deviation, and 71.7% in vertical asymmetry index. The Class III sample showed a prevalence of mandibular asymmetry ranging from 22.93% to 78% in horizontal chin deviation and 80.4% in vertical asymmetry index. Patients seeking orthodontic or orthognathic surgery treatment showed greater prevalence of mandibular asymmetry.

Conclusions: Skeletal Class III malocclusion showed the greatest prevalence of mandibular asymmetry. Mandibular vertical asymmetry showed a marked prevalence in all malocclusions. However, conclusions should be interpreted with caution due to use of convenience samples and low-quality study outcomes. (*Angle Orthod.* 2022;92:118–126.)

KEY WORDS: Asymmetry; Mandible; Angle's malocclusion classification; Prevalence; Systematic review

INTRODUCTION

Facial asymmetry refers to unbalanced proportions in size, shape, and position of bilateral structures on opposite sides of the median sagittal plane (MSP).[1] Mandibular asymmetry has a major impact because of its effects on facial appearance, as it can have permanent and marked effects on facial harmony and

[a] Temporary Professor, Division of Orthodontics, School of Dentistry, Federal University of Goiás, Goiânia, Brazil.
[b] Graduate Student, Graduate Program, School of Dentistry, Federal University of Goiás, Goiânia, Brazil.
[c] Assistant Professor, Department of Orthodontics, University of the Pacific, San Francisco, CA, USA.
[d] Associate Professor, Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor, MI, USA.
[e] Full Professor, Department of Orthodontics, Federal University of Rio de Janeiro, Brazil.
[f] Full Professor, Department of Stomatology, School of Dentistry, Federal University of Goiás, Goiânia, Brazil.
[g] Associate Professor, Division of Orthodontics, School of Dentistry, Federal University of Goiás, Goiânia, Brazil.
Corresponding author: Dr Karine Evangelista, School of Dentistry, Federal University of Goiás, Avenida Universitária esquina com 1[a] Avenida, S/N. Zip Code: 74605-220, Goiânia, Goiás, Brazil
(e-mail: kemar_7@hotmail.com)

Accepted: July 2021. Submitted: April 2022.
Published Online: September 21, 2021

the smile,[2,3] and can affect social and psychological aspects[3–5] of quality of life.[4,5]

A skeletal diagnosis of mandibular asymmetry is established mainly by the location of central points of the mandible, such as Pogonion (Pog), Gnathion (Gn), and Menton (Me). Traditionally, the distance from these central landmarks to the facial MSP is calculated to quantify and classify mandibular skeletal asymmetry as mild (<2 mm), moderate (2–4 mm), or severe (>4 mm),[1,6–8] using cone-beam computed tomography (CBCT)[9,10] or posterior anterior cephalometric radiography (PA cephalogram).[9] In 1988, Habets et al.,[11] introduced the asymmetry index using orthopantomograms to analyze vertical asymmetries in the mandible, in cases of ramus and/or condylar height asymmetries. Index values over 3% were considered to have vertical asymmetry. This method had been applied with better accuracy through three-dimensional exams, such as CBCT.[12]

Studies on facial asymmetries in orthodontic and orthognathic surgery patients clinically found a prevalence of 12%–37% of mandibular asymmetries in different populations and with different anterior posterior skeletal relationships.[13–18] Some authors[6,8,19,20] showed higher prevalence of mandibular asymmetry in Class III malocclusion patients than in Class II or Class I. It was postulated that excessive growth of the mandible in Class III patients could be a risk factor for unbalanced development on both sides of the mandible.[21]

Knowledge of the most prevalent malocclusion with mandibular asymmetry is crucial in following up orthodontic patients to prevent deterioration and minimize risk of developing facial asymmetry. Understanding the prevalence of mandibular asymmetry could also guide researchers analyzing the etiology and morphologic features within each malocclusion. Therefore, this systematic review aimed to provide a synthesis of available evidence to answer the following focused question: "What is the prevalence of mandibular asymmetry in each skeletal sagittal malocclusion?"

MATERIAL AND METHODS

Eligibility Criteria

Inclusion criteria were observational studies without restrictions of year and language, which presented a CoCoPop framework: Condition (Co): mandibular asymmetry diagnosed using computed tomography or PA radiographs, Context (Co): sample with skeletal Class I, II, or III malocclusion classification, Population (P): children, adolescent, and adults.

The following exclusion criteria were applied: studies with animals, studies not investigating prevalence of mandibular asymmetry, mandibular asymmetry related to syndromes and/or congenital disorders, mandibular asymmetry not confirmed by tomographic analysis or PA, or studies based on soft tissue analysis, case reports, reviews, letters, personal opinions, book chapters, and conference abstracts.

Information Sources and Search Strategy

Detailed individual search strategies for each of the following were designed: PubMed/MEDLINE, EMBASE, LILACS, Web of Science, Scopus, and LIVIVO (Table 1). Grey literature searches through Open Grey, Google Scholar, and ProQuest were also undertaken. Google Scholar search was limited to the first 100 most relevant articles published over the last 10 years. References were stored and managed, and duplications removed, using EndNote X7 (Thomson Reuters, Philadelphia, PA, USA). The search strategy was performed in August of 2020 and was updated in March of 2021.

Selection Process

Study selection was completed in two phases. In phase 1, two reviewers (KE, ABT) independently reviewed titles and abstracts of all identified electronic database citations. In phase 2, these reviewers independently applied inclusion and exclusion criteria to the full article texts. The selected article written in French was translated by a speaker certificated in French. This blind process was ensured and registered using Rayyan (https://rayyan.qcri.org).[22] Reference lists of selected studies were then critically assessed.

Data Items Extracted

The first reviewer independently collected the information required from the articles. The second checked this information. In cases of disagreement, a third reviewer participated for consensus decision. The following data were collected from each article: study characteristics, population characteristics, imaging diagnosis methods, criteria for Angle malocclusion classification, mandibular asymmetry diagnosis criteria, and outcome characteristics (Table 2).

Risk of Bias in Individual Studies

The risk of bias for the selected studies was assessed using Joanna Briggs Institute Critical Appraisal Checklist for Studies Reporting Prevalence Data (2014).[23] The two reviewers independently scored the risk of bias as 'low', 'moderate', or 'high', categorizing it as high when up to 49% of the items

Table 1. Databases and Search Strategies[a]

Database	Search Strategy
PubMed	(“Malocclusion"[Mesh] OR “Malocclusion” OR “Malocclusions” OR “Tooth Crowding” OR “Crossbite” OR “Crossbites” OR “Cross Bite” OR “Cross Bites” OR “Angle Classification” OR “Angles Classification” OR “Malocclusion, Angle Class I"[Mesh] OR “Angle Class I Malocclusion” OR “Angle Class I” OR “class I"[Title/Abstract] OR “Malocclusion, Angle Class II"[Mesh] OR “Angle Class II Malocclusion” OR “Angle Class II” OR “class II"[Title/Abstract] OR “Malocclusion, Angle Class III"[Mesh] OR “Angle Class III Malocclusion” OR “Habsburg Jaw” OR “Hapsburg Jaw” OR “Angle Class III” OR “Underbite” OR “class III"[Title/Abstract] OR “Overbite"[Mesh] OR “Overbite” OR “Overbites” OR “Deep Bite” OR “Deep Bites” OR “Over Bite” OR “Over Bites” OR “Dental Overjet” OR “Incisor Protrusion” OR “Incisor Protrusions”) AND (“Facial Asymmetry"[Mesh] OR “Facial Asymmetry” OR “Facial Asymmetries” OR “Asymmetry” OR “mandibular asymmetry” OR “mandibular Asymmetries” OR “chin deviation”)
Embase	(’malocclusion’/exp OR malocclusion OR malocclusions OR ’tooth crowding’/exp OR ’tooth crowding’ OR ’crossbite’/exp OR crossbite OR crossbites OR ’cross bite’/exp OR ’cross bite’ OR ’cross bites’ OR ’angle classification’ OR ’angles classification’ OR ’angle class i malocclusion’ OR ’angle class i’ OR ’class i’ OR ’angle class ii malocclusion’/exp OR ’angle class ii malocclusion’ OR ’angle class ii’ OR ’class ii’ OR ’angle class iii malocclusion’ OR ’habsburg jaw’ OR ’hapsburg jaw’ OR ’angle class iii’ OR underbite OR ’class iii’ OR ’overbite’/exp OR overbite OR overbites OR ’deep bite’ OR ’deep bites’ OR ’over bite’ OR ’over bites’ OR ’dental overjet’ OR ’dental overjets’ OR ’incisor protrusion’ OR ’incisor protrusions’) AND (’facial asymmetry’/exp OR ’facial asymmetry’ OR ’facial asymmetries’ OR ’mandibular asymmetry’/exp OR ’mandibular asymmetry’ OR ’mandibular asymmetries’ OR ’chin deviation’)
Scopus	TITLE-ABS-KEY(Malocclusion OR Malocclusions OR “Tooth Crowding” OR Crossbite OR Crossbites OR “Cross Bite” OR “Cross Bites” OR “Angle Classification” OR “Angles Classification” OR “Angle Class I Malocclusion” OR “Angle Class I” OR “class I” OR “Angle Class II Malocclusion” OR “Angle Class II” OR “class II” OR “Angle Class III Malocclusion” OR “Habsburg Jaw” OR “Hapsburg Jaw” OR “Angle Class III” OR Underbite OR “class III” OR Overbite OR Overbites OR “Deep Bite” OR “Deep Bites” OR “Over Bite” OR “Over Bites” OR “Dental Overjet” OR “Dental Overjets” OR “Incisor Protrusion” OR “Incisor Protrusions”) AND TITLE-ABS-KEY(“Facial Asymmetry” OR “Facial Asymmetries” OR “mandibular asymmetry” OR “mandibular Asymmetries” OR “chin deviation”)
Web of Science	TS=(Malocclusion OR Malocclusions OR “Tooth Crowding” OR Crossbite OR Crossbites OR “Cross Bite” OR “Cross Bites” OR “Angle Classification” OR “Angles Classification” OR “Angle Class I Malocclusion” OR “Angle Class I” OR “class I” OR “Angle Class II Malocclusion” OR “Angle Class II” OR “class II” OR “Angle Class III Malocclusion” OR “Habsburg Jaw” OR “Hapsburg Jaw” OR “Angle Class III” OR Underbite OR “class III” OR Overbite OR Overbites OR “Deep Bite” OR “Deep Bites” OR “Over Bite” OR “Over Bites” OR “Dental Overjet” OR “Dental Overjets” OR “Incisor Protrusion” OR “Incisor Protrusions”) AND TS=(“Facial Asymmetry” OR “Facial Asymmetries” OR “mandibular asymmetry” OR “mandibular Asymmetries” OR “chin deviation”)
LILACS	tw:((tw:(malocclusion OR malocclusions OR “Tooth Crowding” OR crossbite OR crossbites OR “Cross Bite” OR “Cross Bites” OR “Angle Classification” OR “Angles Classification” OR “Angle Class I Malocclusion” OR “Angle Class I” OR “class I” OR “Angle Class II Malocclusion” OR “Angle Class II” OR “class II” OR “Angle Class III Malocclusion” OR “Habsburg Jaw” OR “Hapsburg Jaw” OR “Angle Class III” OR underbite OR “class III” OR overbite OR overbites OR “Deep Bite” OR “Deep Bites” OR “Over Bite” OR “Over Bites” OR “Dental Overjet” OR “Dental Overjets” OR “Incisor Protrusion” OR “Incisor Protrusions” OR “Má Oclusão” OR “Apinhamento de Dente” OR “Classificação de Angle” OR “Má Oclusão dos Dentes” OR maloclusão OR “Mordida Cruzada” OR maloclusión OR “Clasificación de Angle” OR “Dientes Apinados” OR “Mala Oclusión” OR maloclusiones OR “Malposición de los Dientes” OR “Mordida Cruzada” OR “Má Oclusão de Angle Classe I” OR “Classe I de Angle” OR “Maloclusão de Angle Classe I” OR “Maloclusión de Angle Clase I” OR “Clase I de Angle” OR “Classe I” OR “Má Oclusão de Angle Classe II” OR “Classe II de Angle” OR “Maloclusão de Angle Classe II” OR “Angle Classe II” OR “Maloclusión de Angle Clase II” OR “Clase II de Angle” OR “Angle Clase II” OR “Clase II” OR “Má Oclusão de Angle Classe III” OR “Classe III de Angle” OR “Maloclusão de Angle Classe III” OR “Classe III” OR “Maloclusión de Angle Clase III” OR “Clase III de Angle” OR “Clase III” OR sobremordida)) AND (tw:(“Facial Asymmetry” OR “Facial Asymmetries” OR “mandibular asymmetry” OR “mandibular Asymmetries” OR “chin deviation” OR “Assimetria Facial” OR “Assimetrias faciais” OR “assimetria mandibular” OR “assimetrias mandibulares” OR “desvio do queixo” OR “Asimetría Facial” OR “Asimetrías faciales” OR “asimetría mandibular” OR “asimetrías mandibulares” OR “desviación del mentón”))) AND (db:(“LILACS”))
LIVIVO	(Malocclusion OR Malocclusions OR “Tooth Crowding” OR Crossbite OR Crossbites OR “Cross Bite” OR “Cross Bites” OR “Angle Classification” OR “Angles Classification” OR “Angle Class I Malocclusion” OR “Angle Class I” OR “class I” OR “Angle Class II Malocclusion” OR “Angle Class II” OR “class II” OR “Angle Class III Malocclusion” OR “Habsburg Jaw” OR “Hapsburg Jaw” OR “Angle Class III” OR Underbite OR “class III” OR Overbite OR Overbites OR “Deep Bite” OR “Deep Bites” OR “Over Bite” OR “Over Bites” OR “Dental Overjet” OR “Dental Overjets” OR “Incisor Protrusion” OR “Incisor Protrusions”) AND (“Facial Asymmetry” OR “Facial Asymmetries” OR “mandibular asymmetry” OR “mandibular Asymmetries” OR “chin deviation”)
OpenGrey	Malocclusion

Table 1. Continued

Database	Search Strategy
ProQuest Dissertation and Thesis	("Facial Asymmetry" OR "Facial Asymmetries" OR "mandibular asymmetry" OR "mandibular Asymmetries" OR "chin deviation") AND (Malocclusion OR Malocclusions OR "Tooth Crowding" OR Crossbite OR Crossbites OR "Cross Bite" OR "Cross Bites" OR "Angle Classification" OR "Angles Classification" OR "Angle Class I Malocclusion" OR "Angle Class I" OR "class I" OR "Angle Class II Malocclusion" OR "Angle Class II" OR "class II" OR "Angle Class III Malocclusion" OR "Habsburg Jaw" OR "Hapsburg Jaw" OR "Angle Class III" OR Underbite OR "class III" OR Overbite OR Overbites OR "Deep Bite" OR "Deep Bites" OR "Over Bite" OR "Over Bites" OR "Dental Overjet" OR "Dental Overjets" OR "Incisor Protrusion" OR "Incisor Protrusions")
Google Scholar	(Malocclusion OR Crossbite OR Overbite "Deep Bite" OR "Dental Overjet" OR "class I" OR "class II" OR "class III") AND ("Facial Asymmetry" OR "mandibular asymmetry" OR "chin deviation")

[a] Search strategies were drafted for all databases included in this study by using specific word combinations and truncations with the support of a librarian.

scored 'yes', moderate when 50%–69% scored 'yes', and low when over 70% scored 'yes'. Any disagreement between the reviewers in each phase was resolved by discussion and agreement between them. The consensus involved a third reviewer (JV-N) for final decision.

Summary Measurements

Predictor variables were patients with sagittal skeletal malocclusions, described as Class I, II, and/or III. The only outcome variable was the prevalence of mandibular asymmetry described using frequency rates.

Synthesis of Results

Mandibular asymmetry prevalence was evaluated through qualitative analysis. Heterogeneity of the studies was calculated using the Cochran's Q method and the value of I^2, where a P value $<.05$ by the Q and I^2 value greater than 50% was considered substantial heterogeneity. Meta-analysis of mandibular asymmetry prevalence pooling random effects with arcsine transformation (quality effects) was planned to minimize the effect of extreme prevalence on overall estimates. However, the high heterogeneity of the studies precluded the quantitative data synthesis. The agreement between both reviewers in phases 1 and 2 was tested by Cohen's kappa test. The significance level (null hypothesis) was rejected at a 5% level ($P <$ .05).

Risk of Bias Across Studies and Certainty of Evidence

Analyses for small-study effects, publication bias, and exploratory subgroup analyses were planned if an adequate number of studies were identified. The Grading of Recommendation Assessment, Development and Evaluation (GRADE) system of rating quality of evidence was performed to show certainty of outcome in this review.[24] GRADE considered directness of evidence, consistency of results, precision of estimates, risk of publication bias, and magnitude of the effect.

RESULTS

Study Selection

Through seven databases, 5,132 citations were identified and 748 found in grey literature were added in phase 1. After removing duplicates, 2275 articles remained for screening based on title and abstract. After comprehensive evaluation of abstracts, a final sample of 18 articles was read in full text, of which five met the inclusion criteria.[6,25–28] The agreement between both reviewers was almost perfect (kappa = 0.98). Figure 1 illustrates the study selection and identification process.

Study Characteristics

Table 2 summarizes the extracted data of all studies. The five selected studies were all published between 2009 and 2018 from the following countries: Brazil,[6] France,[27] Iran,[25] Spain,[26] and Turkey.[24] The total sample size was 1389 patients (491 females and 785 males), and no sex was reported for 114 cases extracted in one study.[27] Sample sizes ranged from 61 to 952 in different groups of malocclusion, with ages between 18 and 75 years. Settings of the whole sample included oral radiology clinic databases (n = 952),[6] orthognathic surgery clinical records (n = 278)[26,28] and orthodontic clinical records (n = 159).[27]

Sample Classification

All selected studies used ANB angle for sagittal malocclusion diagnosis.[6,25–28] Four studies considered mandibular asymmetry using the horizontal position of the chin [6,25,26,28] and, another[27] reported the asymmetry index to identify vertical asymmetry in the mandible.

Mandibular Asymmetry Prevalence

Mandibular asymmetry ranged from 17.43% to 72.95% in the overall sample. According to mandibular asymmetry direction, horizontal chin deviation showed a prevalence of asymmetry in the Class I sample of 17.66% to 55.6%,[6,26] and 68.98% in vertical asymmetry index.[27] In Class II patients, prevalence of mandibular asymmetry varied from 10% to 25.5% in horizontal chin deviation,[6,26,28] and 71.7% in vertical asymmetry index.[27] Class III sample showed prevalence of mandibular asymmetry ranging from 22.93% to 78% in horizontal chin deviation [6,25,26,28] and 80.4% in vertical asymmetry index.[27]

Regarding methods of image diagnosis, the prevalence of mandibular asymmetry showed rates of 34.95% in overall malocclusion using PA cephalogram[26] and 17.43% to 72.95% using tomographic images.[6,27] According to patient settings, one study showed a sample from the database of an oral radiology clinic[6] and four studies presented patients seeking for treatment for orthodontics[27] or orthognathic surgery.[25,26,28] Prevalence of mandibular asymmetry showed greater rates in patients seeking orthodontic or orthognathic surgical treatment, ranging from 34.95% to 72.95%.

Risk of Bias within the Studies

Figure 2 and Table 3 present the complete list of quality assessment items. No study satisfied all risk of bias criteria. However, most of the studies were considered methodologically acceptable. Of the five studies, two showed a low risk of bias,[6,27] one showed moderate risk[26] and two showed high risk.[25,28] The main methodological limitations of the studies were related to representation of the target population (Question 1), since the samples were all from specific settings.

Heterogeneity Analysis

Considerable heterogeneity between studies was found in all malocclusion analyses, as seen by I^2 index over 96% and Q ($P < .001$). Due to this result, a meta-analysis wasn't performed.

Risk of Bias Across the Studies and Certainty of Evidence

Due to the limited number of studies included, publication bias analysis was not performed. Inconsistency, indirectness, and imprecision were rated as serious issues. According to the GRADE criteria, confidence in cumulative evidence was considered

Table 2. Summary of Descriptive Characteristics of Articles Included[a]

Author, Year, Country	Study Design	Sample n Female/Male	Mean/ Range of Age (yr)	Settings	Imaging Analysis	Data Collection Examiner (n) Calibration/ Reproducibility
Kilic et al., 2009[25] Turkey	Observational	61 (31/30) 32,16/16) Control group 29, 15/14 Class III	21.44 19.20	Orthognathic surgery patient records	PA ceph	1 examiner Paired t-test (values not informed)
Queiss et al., 2010[28] France	Observational	114	NA	Orthognathic surgery patient records at University Hospital	CT	NA
Thiesen et al., 2017[6] Brazil	Observational	952 317/635	18-75	Database of oral radiology clinic	CBCT	3 examiners Intraobserver reliability ICC > 0.90
Eslamipour et al., 2017[26] Iran	Observational	103 58/45	23.47	Orthognathic surgery patient records at Dentistry University	PA ceph	Not informed
Mendoza et al., 2018[27] Spain	Observational	159 85/74	32.32	Orthodontic patient records at University Hospital	CBCT	2 examiners Intraobserver CV-0.70% – 1.13% Inter-observer CV- 1.21%-1.49% Intra and inter-observer error measurement-< 0.16 mm

[a] CBCT indicates cone-beam computed tomography; CT, computed tomography; CV, coefficient of variation; NA, not available; OR, odds ratio; PA ceph, posteroanterior cephalogram.

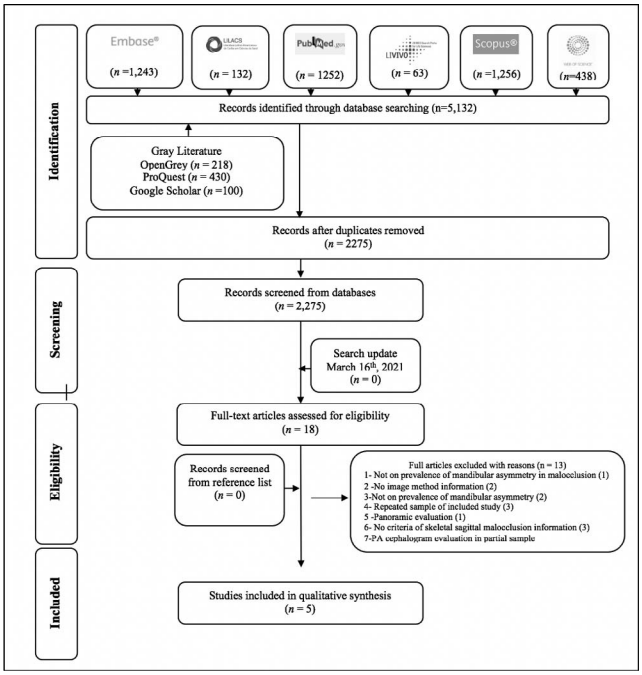

Figure 1. PRISMA flow diagram of literature search and selection criteria.

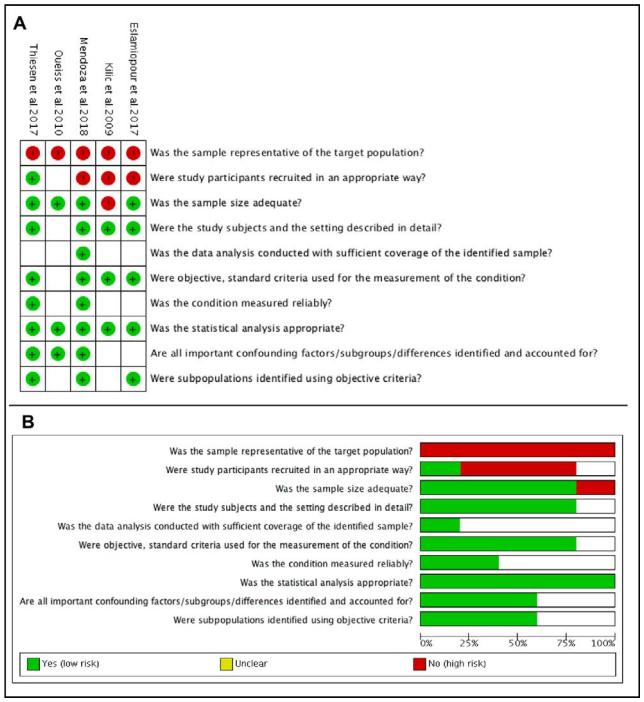

Figure 2. Risk-of-bias and applicability concerns graph: (A) risk-of-bias graph; (B) risk-of-bias summary.

Table 2. Extended

Criteria for Angle's Malocclusion Classification	Criteria for Mandibular Asymmetry Diagnosis	Prevalence of mandibular asymmetry				Secondary Results (Regions of Mandibular Asymmetry)	Conclusions
		Overall Malocclusions n/Total %	Class I n/Total %	Class II n/Total %	Class III n/Total %		
ANB angle	Chin deviation (>2mm)	—	——	——	21/29 78%	—	Subjects with Class III dentofacial deformity could have frontal skeletal facial asymmetries, predominantly in the lower third of their face.
ANB angle	Chin deviation (>3 mm)	—	NA	4/40 10%	10/34 29%	—	Skeletal Class III are related to accentuated asymmetries
ANB angle	Chin (Gn) deviation (> 4mm)	166/952 17.43%	71/402 17.66%	45/332 13.55%	50/218 22.93%	—	Mandibular asymmetry was 61% higher in skeletal Class III when compared with skeletal Class II.
ANB angle	Chin deviation	36/103 34.95%	5/9 55.6%	12/47 25.5%	19/47 40.4%	—	The trend toward an increased incidence of facial asymmetry in the Class III population was interesting but was not statistically significant.
ANB angle	Asymmetry index in condylar height >3%	116/159 72.95 %	42/61 68.9%	39/54 71.7%	35/44 80.4%	Asymmetry index of condyle height > 10% associated to Class III (OR =2.882)	Linear and volumetric asymmetries were more prevalent among Class III patterns. Significant associations were found between condylar height asymmetries >10% and skeletal class III.

Table 3. Risk of Bias in Individual Studies. JBS Critical Appraisal for. Studies Reporting Prevalence Data[a,23]

Author, Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total	Risk of Bias
Kilic et al., 2009[25]	N	N	N	Y	U	Y	U	Y	U	U	40%	High
Oueiss et al., 2010[28]	N	U	Y	U	U	U	U	Y	Y	U	30%	High
Eslamipour et al., 2017[26]	N	N	Y	Y	U	Y	U	Y	U	Y	50%	Mod
Thiesen et al., 2017[6]	N	Y	Y	Y	U	Y	Y	Y	Y	Y	70%	Low
Mendoza et al., 2018[27]	N	N	Y	Y	Y	Y	Y	Y	Y	Y	80%	Low

Q1 Was the sample representative of the target population?
Q2 Were study participants recruited in an appropriate way?
Q3 Was the sample size adequate?
Q4 Were the study subjects and the setting described in detail?
Q5 Was the data analysis conducted with sufficient coverage of the identified sample?
Q6 Were objective, standard criteria used for the measurement of the condition?
Q7 Was the condition measured reliably?
Q8 Was the statistical analysis appropriate?
Q9 Are all important confounding factors/subgroups/differences identified and accounted for?
Q10 Were subpopulations identified using objective criteria?
Total 1/4 SY/applicable items (the not applicable (NA) items were excluded from the sum).
Risk of bias was categorized as high when the study reached a score of up to 49% 'yes', moderate when the study reached a score of 50%–69% 'yes', and low when the study reached a score of more than 70% 'yes'.
[a] N indicates no; NA, not applicable; U, unclear; Y, yes.

"very low" for the outcome evaluated (prevalence of mandibular asymmetry), due to the convenience sampling of all studies.

DISCUSSION

In this systematic review, prevalence of mandibular asymmetry was assessed overall in sagittal skeletal malocclusions and individually in Class I, II, and III malocclusions. Although quantitative analyses regarding heterogeneity exposed meaningful rates, the qualitative prevalence rates could be explored and showed new perspectives for research and clinical application in mandibular asymmetry.

Mandibular asymmetry is a craniofacial feature occurring in all types of sagittal malocclusion.[6,26,27] Greater prevalence of mandibular asymmetry in Class III patients found in this systematic review was already highlighted in many studies.[6,8,16,19,20,26–28] However, with regard to Class I and Class II malocclusions, prior studies showed inconclusive results. In Class II samples, some studies reported lesser prevalence of mandibular asymmetry among all malocclusions,[6,26] while another showed similar rates with Class I malocclusion.[27] Likewise, Class I malocclusions showed varied prevalence rates, sometimes smaller than Class III,[6] sometimes greater.[26,27] This review brings focus to the prevalence rates among all malocclusions. Although there was strong evidence for the predominance of mandibular asymmetry in Class III patients, Class I samples also showed considerable frequency of mandibular asymmetry. The results also indicated that Class II malocclusion had the smallest prevalence of mandibular asymmetry, 9%–19% smaller than Class III patients and 4%–30% smaller than Class I patients, in agreement with Thiesen et al.[6]

According to patient settings, the results showed new information about mandibular asymmetry in an orthognathic surgery setting. Severt and Proffit[14] analyzed a large sample of orthognathic surgery patients with facial and/or mandibular asymmetries. Asymmetric patients showed mandibular asymmetry with chin deviation, more commonly in Class III (78%) and Class I (58%) malocclusions.[14] This systematic review also found a greater prevalence of mandibular asymmetry in Class III patients. A Class I sample in an orthognathic surgery setting was available in one report only,[26] and found 56% of patients with mandibular asymmetry, similar to findings in Severt and Proffit.[14] Thiesen et al.[21] compared mandibular asymmetry between cut-off values of chin deviation, using values under and over 4 mm as orthodontic and orthognathic surgery parameters, respectively. They found prevalence rates of 27.2% for orthodontic and 17.6% for orthognathic surgery patients. In light of these rates, it should be noted that this asymmetric condition was a common craniofacial deformity in patients seeking orthognathic treatment, except for those with Class II malocclusion, which occurred in 10%–20.5% of patients in this systematic review. These results suggest that mandibular asymmetry in surgical patients was more common in malocclusion types with potential excessive mandibular growth and/or normal growth, such as Class III and Class I malocclusions, than in patients with lower potential for mandibular growth, such as Class II patients.

Other valuable information in the current study involved the diagnosis of mandibular asymmetry using different imaging methods. Computed tomography incorporated different measurements into image analysis to enhance diagnostic methods and identify different bone regions related to asymmetry.[10,12,29,30] In

terms of imaging method, the results showed that prevalence of mandibular asymmetry could be underestimated, as prevalence rates for all malocclusions increased at least 2.5 times using the asymmetry index in tomographic images.[27] Greater prevalence of mandibular asymmetry using CT or CBCT imaging must be viewed with caution when considering the clinical manifestation of facial asymmetry. This approach can show a patient's vertical asymmetry, as seen in ramus and condylar height, with different vertical positions in the gonion region and not necessarily due to chin deviation. Craniofacial bones located in upper facial regions, such as the maxilla, zygoma, and temporal bone (glenoid fossae), can have an important function in masking asymmetric mandibular conditions.[30]

Previous studies using the asymmetry index found a difference in ramus height between sides in asymmetric Class III[31] and Class II patients.[32] Mendoza et al.[27] also found considerable rates of condylar height asymmetry in all sagittal malocclusions. In this systematic review, chin deviation was the parameter mainly used to consider mandibular asymmetry.[6,25,26,28] The asymmetry index was considered only in one study in all sagittal malocclusions.[27] Thus, a clinical question arose after this systematic review: Are vertical asymmetries a common feature in all malocclusions? Future studies with different designs and control groups could better respond to this question.

Limitations

In this systematic review, only one study included a large sample size with 952 participants[6] and only adult samples were assessed. In addition, different criteria for mandibular asymmetry might have had an influence on the estimates of prevalence, as only one study which considered asymmetry index was included.[27] Additionally, comparative studies with orthodontic and orthognathic surgery patients with uniform study designs are needed to better understand the prevalence of mandibular asymmetry according to malocclusion severity. The studies only examined mandibular asymmetries in sagittal malocclusions, without considering vertical growth patterns.

Other Information

*Protocol and registration*A systematic review protocol based on Preferred Reporting Items for Systematic Reviews and Meta Analyses Protocols (PRISMA-P)[33] was drafted and registered in the Prospective Register of Systematic Reviews (PROSPERO), as CRD42020207247. In addition, reporting was based on the PRISMA 2020 checklist.[34]

CONCLUSIONS

According to this review, the following conclusions may be considered:

- Skeletal Class III malocclusion shows the greatest prevalence of mandibular asymmetry.
- Skeletal Class II malocclusion has the lowest prevalence of mandibular asymmetry.
- Vertical asymmetry shows a marked prevalence in all malocclusions.
- However, conclusions should be interpreted with caution due to convenience sampling and low-quality study outcomes.

ACKNOWLEDGMENTS

Support

This study received partial support from Capes (Financial code 001) and NIH grant NIDCR R01 DE024450.

Competing Interests

The authors declare no competing interests.

Data Availability Statement

Data are available on request to the corresponding author by e-mail.

REFERENCES

1. Peck BS, Peck L, Kataja M. Skeletal asymmetry in esthetically pleasing faces. *Angle Orthod*. 1991;61:43–48.
2. Rhodes G, Sumich A, Byatt G. Are average facial configurations attractive only because of their symmetry? *Psych Sci*. 1999;10:52–58.
3. Taylor HO, Morrison CS, Linden O, et al. Quantitative facial asymmetry: using three-dimensional photogrammetry to measure baseline facial surface symmetry. *J Craniofac Surg*. 2014;25:124–128.
4. Ryan FS, Barnard M, Cunningham SJ. Impact of dentofacial deformity and motivation for treatment: a qualitative study. *Am J Orthod Dentofac Orthop*. 2012;141:734–742.
5. Soh CL, Narayanan V. Quality of life assessment in patients with dentofacial deformity undergoing orthognathic surgery—a systematic review. *Int J Oral Maxillofac Surg*. 2013;42:974–980.
6. Thiesen G, Gribel BF, Kim KB, Pereira KCR, Freitas MPM. Prevalence and associated factors of mandibular asymmetry in an adult population. *J Craniofac Surg*. 2017;28:e199–e203.
7. Masuoka N, Momoi Y, Ariji Y, et al. Can cephalometric indices and subjective evaluation be consistent for facial asymmetry? *Angle Orthod*. 2005;75:651–655.
8. Good S, Edler R, Wertheim D, Greenhill D. A computerized photographic assessment of the relationship between skeletal discrepancy and mandibular outline asymmetry. *Eur J Orthod*. 2006;28:97–102.
9. Yousefi F, Rafiei E, Mahdian M, Mollabashi V, Saboonchi SS, Hosseini SM. Comparison efficiency of posteroanterior

cephalometry and cone-beam computed tomography in detecting craniofacial asymmetry: a systematic review. *Contemp Clin Dent*. 2019;10:358–371.
10. Al-Hadidi A, Cevidanes LHS, Mol A, Ludlow J, Styner M. Comparison of two methods of quantitative assessment of mandibular asymmetry using cone beam computed tomography image volumes. *Dentomaxillofac Radiol*. 2011;40: 351–357.
11. Habets LL, Bezuur JN, Naeiji M, Hansson TL. The Orthopantomogram, an aid in diagnosis of temporomandibular joint problems. II. The vertical symmetry. *J Oral Rehabil*. 1988;15:465–471.
12. Halicioglu K, Celikoglu M, Yavuz I, Sekerci AE, Buyuk SK. An evaluation of condylar and ramal vertical asymmetry in adolescents with unilateral and bilateral posterior crossbite using cone beam computed tomography (CBCT). *Aust Orthod J*. 2014;30:11–18.
13. Sheats RD, McGorray SP, Musmar Q, et al. Prevalence of orthodontic asymmetries. *Semin Orthod*. 1998;4:138–145.
14. Severt TR, Proffit WR. The prevalence of facial asymmetry in the dentofacial deformities population at the University of North Carolina. *Int J Adult Orthodon Orthognath Surg*. 1997; 12:171–176.
15. Bailey LJ, Haltiwanger LH, Blakey GH, et al. Who seeks surgical orthodontic treatment: a current review. *Int J Adult Orthodon Orthognath Surg*. 2001;16:280–292.
16. Piao Y, Kim SJ, Yu HS, et al. Five-year investigation of a large orthodontic patient population at a dental hospital in South Korea. *Korean J Orthod* 2016;46:137–145.
17. Willems G, De Bruyne I, Verdonck A, et al. Prevalence of dentofacial characteristics in a Belgian orthodontic population. *Clin Oral Investig*. 2001;5:220–226.
18. Samman N, Tong AC, Cheung DL, et al. Analysis of 300 dentofacial deformities in Hong Kong. *Int J Adult Orthodon Orthognath Surg*. 1992;7:181–185.
19. Choi HW, Kim B, Kim JY, Huh JK, Park KH. Three-dimensional computed tomography evaluation of craniofacial characteristics according to lateral deviation of chin. *Maxillofac Plast Reconstr Surg.* 2019;6;41:57.
20. Katsumata A, Fujishita M, Maeda M, Ariji Y, Ariji E, Langlais RP. 3D-CT evaluation of facial asymmetry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 200;99:212–220.
21. Thiesen G, Gribel BF, Freitas MPM, Oliver DR, Kim KB. Mandibular asymmetries and associated factors in orthodontic and orthognathic surgery patients. *Angle Orthod*. 2018;88:545–551.
22. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayann: a web and mobile app for systematic reviews. *Syst Rev*. 2016;5:210.
23. Munn Z, Moola S, Riitano D, Lisy K. The development of a critical appraisal tool for use in systematic reviews addressing questions of prevalence. *Int J Health Policy Manag*. 2014;3:123–128.
24. Guyatt GH, Oxman AD, Vist GE, et al. 2008. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336:924–926.
25. Kilic N, Kilic SC, Catal, G Facial asymmetry in subjects with class III malocclusion. *Aust Orthod J*. 2009; 25:158–162.
26. Eslamipour F, Borzabadi-Farahani A, Le BT, Shahmoradi M. A retrospective analysis of dentofacial deformities and orthognathic surgeries. *Ann Maxillofac Surg*. 2017;7:73–77.
27. Mendoza LV, Bellot-Arcís C, Montiel-Company JM, García-Sanz V, Almerich-Silla JM, Paredes-Gallardo V. Linear and volumetric mandibular asymmetries in adult patients with different skeletal classes and vertical patterns: a cone-beam computed tomography study. *Sci Rep.* 2018;17;8: 12319.
28. Oueiss A, Pages C, Treil J, Braga J, Baron P, Faure J. Study of asymmetries in the severe antero-posterior disharmonies. *Orthod Fr*. 2010;81:235–244.
29. Lim YS, Chung DH, Lee JW, Lee SM. Reliability and validity of mandibular posterior vertical asymmetry index in panoramic radiography compared with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2018;153: 558–567.
30. Evangelista K, Ferrari-Piloni C, Barros LAN, et al. Three-dimensional assessment of craniofacial asymmetry in children with transverse maxillary deficiency after rapid maxillary expansion: a prospective study. *Orthod Craniofac Res.* 2020;23:300–312.
31. Qu GL, Xu J, Zhou Q. Evaluation of the spatial position and correlation of mandibular ramus in skeletal Class III patients with mandibular asymmetry. *J Craniofac Surg*.2019;30: e439–e442.
32. Thiesen G, Gribel BF, Freitas MPM, Oliver DR, Kim KB. Craniofacial features affecting mandibular asymmetries in skeletal Class II patients. *J Orofac Orthop*. 2017;78:437–445.
33. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M et al. PRISMA-P Group: Preferred reporting items for systematic review and meta-analysis protocols (PRISMAP) 2015 elaboration and explanation. *BMJ*. 2015; 349:g7647.
34. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71.