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Oral Myofunctional and Articulation Disorders in Children with Malocclusions: A Systematic Review

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Keywords

Orofacial myofunctional disorders · Articulation disorders · Malocclusion

Abstract

Background: Relationships between malocclusion and orofacial myofunctional disorders (OMD), as well as malocclusions and articulation disorders (AD) have been described, though the exact relationships remain unclear. Given the high prevalence of these disorders in children, more clarity is needed. ***Summary:*** The purpose of this study was to determine the association between OMD (specifically, bruxism, deviate swallowing, caudal resting tongue posture, and biting habits), AD, and malocclusions in children and adolescents aged between 3 and 18 years. To conduct a systematic review, 4 databases were searched (MEDLINE, Embase, Web of Science, and Scopus). The identified articles were screened for the eligibility criteria. Data were extracted from the selected articles and quality assessment was performed using the tool of Munn et al. [Int J Health Policy Manag. 2014;3:123–81] in consensus. Using the search strategy, the authors identified 2,652 articles after the removal of duplicates. After reviewing the eligibility criteria, 17 articles were included in this study. One of the included articles was deemed to have an unclear risk of bias, whereas all other articles were considered to have a low risk of bias. The articles showed a relationship between anterior open bite and apico-alveolar articulatory distortions, as well as between anterior open bite and deviate swallowing. For the biting habits, bruxism, and low tongue position no clear conclusions could be drawn. ***Key Messages:*** The current review suggests a link between specific types of malocclusion and OMD and AD. However, more high-quality evidence (level 1 and level 2, Oxford Levels of Evidence) is needed to clarify the cooccurrence of other OMD, AD, and malocclusions.

Introduction

Facial morphology and its associated structures are related to orofacial functions, such as oral habits and articulation. Orofacial myofunctional disorders (OMD) are dysfunctions of the oral and facial musculature (i.e., lips, jaw, tongue, and oropharynx) that affect oral posture and functions negatively [1, 2]. OMD are said to be present in 48% of the population and their prevalence is even higher

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in children presenting with malocclusions [3, 4]. In a public school setting, up to 50% of the children treated by a speech-language pathologist could present with OMD [4]. The following orofacial myofunctional habits will be considered in this review, though this list is not exhaustive. Bruxism can be defined as repetitive jaw movement, which can consist of clenching or grinding the teeth, as well as bracing or thrusting the mandible [5]. Deviate swallowing can be described as swallowing with excessive perioral muscle tension [2, 6]. Rather than exerting vertical pressure and a front to back motion, the tongue pushes forward or laterally into the teeth [2, 6]. In a caudal resting tongue position, the tongue is directed to the lower anterior teeth rather than being sucked up to the palate [2, 3]. Lastly, biting habits, which can be defined as biting on the nails, lips, or objects [7], and has been considered behavior similar to sucking habits [8], will be considered. A causal relationship between these OMD and malocclusions, a group of developmental disorders that result in an irregular position of the teeth or an abnormal relationship of the dental arches [9–11], is theorized in the literature. The "tropic premise" of Mew [12] hypothesizes that tooth and jaw positions are not only determined by genetics but also guided by oral posture. This means that OMD, such as a low tongue position, could negatively impact facial and dental development. While dental structures have been proven to be resistant to short and great forces, a long-term light force can move the teeth [12–14]. Consequently, OMD that exert long-term pressure on teeth, such as a caudal tongue resting posture can be hypothesized to change the dentition and occlusion [12, 13]. On the other hand, shorter-duration habits, such as deviate swallowing [15] or bruxism [16], would have less of an effect on the dentition and occlusion [13]. However, while most of these theories are based on the literature, they remain opinion based. To the best of our knowledge, no conclusive evidence or theory on a relationship between OMD and malocclusions is available at the moment.

In addition, the presence of malocclusion may negatively impact articulation or speech sound production. The articulation of sounds, and specifically consonants, is generally characterized by 3 dimensions, i.e., voicing, manner, and place of production [17]. It is estimated that 2–24% of school-aged children present with some kind of articulation disorder (AD) [18]. Correlations between malocclusions and AD have been reported [19], which is unsurprising as the production of certain speech sounds necessitates the teeth [20]. In populations with cleft palate, it is well known that changes in the occlusion and dental morphology are related to specific AD [21]. In non-cleft palate populations as well, AD have been found to cooccur with malocclusions [20, 22]. Especially sibilant sounds such as /s/ and /z/ appear to be disordered in the presence of a malocclusion [19, 22]. However, the exact relationship between AD and malocclusions remains unclear. Some authors have suggested causal relationships, but a potential for compensation has also been suggested [14, 19].

Finally, malocclusion and its contributing factors are important to discuss. The increasing prevalence of malocclusion means it can be considered an important public health problem [23, 24]. Untreated malocclusions can negatively impact a patient's physical, social, and psychological well-being [25, 26]. Examples of physical consequences are an increased risk for temporomandibular disorders or dental trauma [26]. Malocclusions are also often present in people with obstructive sleep apnea [27], which leads to more serious health risks such as increased mortality and cardiovascular issues [28, 29]. Moreover, orthodontic therapy that typically remedies malocclusions is expensive for both the patient and society in terms of direct costs (e.g., material and transport costs), indirect costs (e.g., loss of work time for the adult who accompanies the child), and intangibles (e.g., quality of life) [30]. Knowing more about the link between OMD, AD, and malocclusions is, therefore, important for orthodontists as well as for speech-language pathologists [31]; OMD and AD have been said to complicate orthodontic therapy and cause relapse [32].

The hypothesized relationships between malocclusion and OMD or AD have been considered in the literature. Many prevalence and association studies have been carried out to investigate this connection. Doğramacı and Rossi-Fedele [33] investigated the link between nonnutritive sucking habits and malocclusion using a systematic review and meta-analysis. They found significant associations; digit suckers were more likely to develop increased overjet (i.e., horizontal difference between the upper and lower incisors) [13], whereas pacifiers suckers were more likely to exhibit posterior crossbite [33] (i.e., the lower premolars or molars lie buccally to the upper premolars or molars) [13]. Furthermore, the longer a nonnutritive sucking disorder persisted, the bigger the risk for malocclusion was [33]. Another systematic review by Schmid et al. [34] looked specifically at pacifier sucking and its effect on orofacial structures and found, similarly to Doğramacı and Rossi-Fedele [33], that a pacifier sucking habit was associated with posterior crossbite. They also found an association with anterior open bite (AOB; i.e., when the teeth are in occlusion, the upper and lower incisors do not occlude) [13] and noted that many of the studies had a moderate to high overall risk of bias [34] using the risk of bias in nonrandomized studies of intervention tool [35], which considers confounding factors and selection bias, among other things. Finally, apart from sucking habits, the evidence regarding the impact of mouth breathing on malocclusion has been summarized using a systematic review [36]. Fraga et al. [36] found that Angle class II, division 1 malocclusion (i.e., the mandible is retruded relative to the maxilla, with lingually inclined upper front teeth) [13] was more prevalent in children who showed oral breathing. All studies included in the review were deemed to be of moderate to low quality. Nevertheless, OMD are not comprised solely of sucking habits and mouth breathing. Other topics, such as bruxism, deviate swallowing, caudal resting tongue position, and biting habits, as well as AD, should be considered.

When reviewing a possible relationship between OMD, articulation, and malocclusion, school-aged children between 3 and 18 years of age are of particular interest. OMD and AD are highly prevalent in children [3, 4, 18], and starting at about 3 years of age the negative effects of sucking habits become apparent in the primary dentition [37]. Occlusion in the primary dentition is of importance as it guides permanent dentition development [38]. However, not all malocclusions and sucking habits persist over the years [39]. It is unclear to what extent sucking habits in early life influence malocclusions later in life [40], but there are indications that malocclusions should be treated earlier rather than later to prevent further disturbances of the growth of the mandible, the maxilla, and the dental arch [41]. Similarly, there is some research indicating the benefits of early treatment of OMD, though the ideal treatment age remains unclear [42]. In Belgium, orthodontic therapy is typically initiated between 10 and 14 years of age [43], with the majority of treatments taking place between 6 and 18 years of age [43, 44]. Therefore, the group of children and adolescents between 3 and 18 years old was considered to be of interest in this review.

Considering the discussed literature, there consequently appears to be an interrelationship between malocclusion and OMD or AD. Nevertheless, the exact relationship between malocclusion, OMD, and AD remains unclear. To the best of our knowledge, no overview of the existing literature has been written focusing specifically on the effects of bruxism, deviate swallowing, caudal resting tongue posture, biting habits, and AD on malocclusion. Therefore, this study aims to systematically review whether OMD and/or AD is more often present in children and adolescents with malocclusion compared to children and adolescents without malocclusions. The specific research question used was: are children and adolescents between 3 and 18 years of age, who have a malocclusion, compared to those without malocclusion, at greater risk for OMD (bruxism, deviate swallowing, caudal resting tongue posture, and biting habits) and/or AD?

Methods

The research question was addressed using a systematic review. Before the start of this review, the protocol was designed and registered in Prospero (PROSPERO 2018 CRD42018090657).

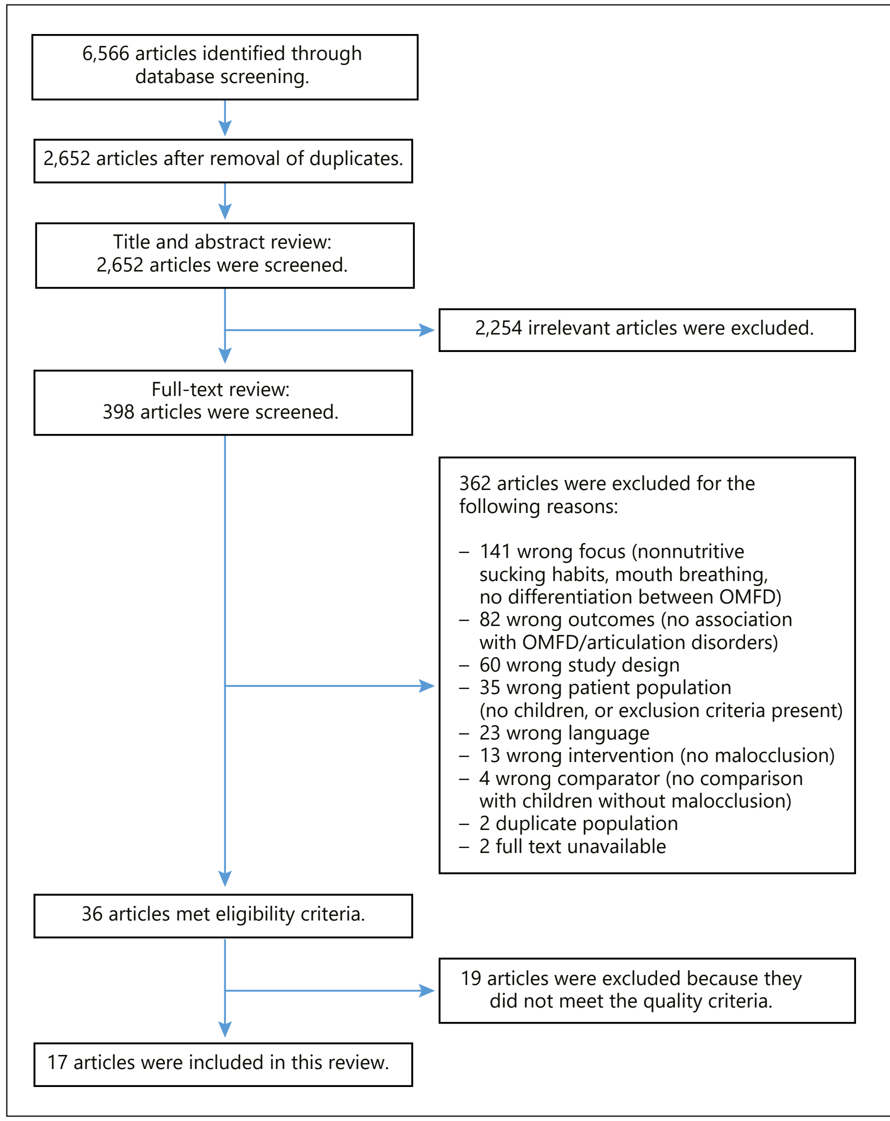
Inclusion and Exclusion Criteria

The aim was to include studies with the following characteristics: controlled trials, longitudinal trials, and cross-sectional studies. The population included in this review were children and adolescents between 3 and 18 years of age with malocclusion. These children and adolescents had to have normal hearing and cognition and should not have received any orthodontic treatment. The study needed to determine the presence of OMD and/or AD in these children. Moreover, these results needed to be compared to the presence of OMD and/or AD in children without malocclusion or establish an association between the malocclusion and OMD/AD. The studies needed to use questionnaires or examinations to determine the occlusal status and the presence of OMD and/or AD. Moreover, only studies with a low risk of bias as determined by an assessment tool (see below) were included in this review.

Case reports, review articles, ideas, editorials, and opinions, as well as studies that grouped all OMD together, were excluded from this review. Medically comprised populations or populations with craniofacial anomalies were excluded as well. In the initial search, all OMD were considered for inclusion in this review. However, during the full-text review, the authors decided to narrow the scope of the review, excluding studies focusing solely on nonnutritive sucking habits or mouth breathing, as these topics have already been addressed in the systematic reviews of Doğramacı and Rossi-Fedele [33], Schmid et al. [34], and Fraga et al. [36].

Identification of Studies

Based on the described inclusion and exclusion criteria, a search strategy was determined. The search strategy and search terms used consisted of 3 parts. The first part described the population, i.e., children and adolescents. These search terms were used along with common synonyms (e.g., youth and teenager) and database-specific search terms. The second part, connected to the first part by "AND", focused on malocclusion, including synonyms and specific disorders. Search terms included malocclusion, open bite, crossbite, overbite, deep bite, angle classification, and their respective synonyms, alternative spellings, and database-specific search terms. The third part of the search string, connected to the first 2 by "AND", defined the OMD and AD in 2 different parts. The following terms were used for OMD: orofacial myofunctional disorders, swallowing, open mouth posture, tongue resting position, bruxism, and biting habits, along with their synonyms and alternative spellings. Connected to OMD with "OR," AD, and possible synonyms were the



Color version available online

Fig. 1. Overview of the screening and selection process of articles.

final part of the search string. Each search strategy was adapted to the database used. The initial search also included search strings for sucking habits and mouth breathing, but those articles were later excluded due to a change of scope for this review.

The following databases were searched in December 2017: MEDLINE (using the PubMed interface), Embase, Web of Science, and Scopus. The search was rerun in May 2019 to include more recent publications. Articles in English, French, or Dutch were considered for this systematic review, as these are the languages the authors are proficient in. No restrictions were set for the year of publication. After the removal of duplicates, 2,652 articles (Fig. 1) were identified and included in the title and abstract screening.

Protocol

After identification of the initial pool of articles, the first and second authors, both speech-language pathologists, started the screening process. All screenings were performed independently, but in case of doubt or disagreement a consensus between both researchers was required. First title and abstract screenings were performed, resulting in 398 remaining articles. After this stage, the full texts of the articles were screened, and 36 articles were identified that met the inclusion criteria. The final articles were excluded based on the quality and risk of bias assessment. The quality of each article was assessed using the assessment tool described by Munn et al. [45], as this tool was specifically developed for systematic reviews with a question of prevalence. The working group of Munn et al. [45] developed an easy-to-use tool that, among other things, evaluates sample size, recruitment, and reliable data collection and analysis. The following 2 supplementary questions based on Genaidy et al. [46] were added: "Is the hypothesis/aim/objective of the study clearly described?" and "Are the main findings of the study clearly described?". All questions could be answered as "high risk," "low risk," "unclear," or "not applicable." For example, when considering the validity of the assessments, studies with clear definitions and diagnostic criteria, as well as validated and objective instruments, were considered "low risk." Studies with tools that were

Table 1. Overview of the articles discussing the association between articulation and malocclusion

Study	Population	Articulation assessment	Orthodontic assessment	Results
Botero-Mariaca et al. [47][a]	264 Colombian children aged 8–16 years (mean ± SD: 11.62 ± 2.5) 56.1% ♀ and 43.9% ♂ 132 children with AOB 132 children with normal occlusion	Unclear who performed the assessment Articulation test Normal Distortion because of lingual interposition Distortion because of lingual thrust Substitution Omission	Unclear who performed assessment AOB	Distorted speech sounds in 39.8% of cases in AOB vs. 9.1% in normal occlusion ($p = 0.001$) Lingual interposition in 40.5% in AOB vs. 16.7% in normal occlusion ($p < 0.001$) Lingual thrust in 27.3% in AOB vs. 0.7% in normal occlusion ($p = 0.001$) Tongue protrusion in 8.3% in AOB vs. 1.5% in normal occlusion ($p = 0.001$) Contact with palatine rugae in 24.2% in AOB vs. 37.9% in normal occlusion ($p = 0.001$) Magnitude of the AOB was significantly related to contact of the tongue with the palatal rugae ($p = 0.001$), the lower teeth ($p = 0.025$), or tongue protrusion ($p = 0.001$) Distortions were found to be a risk factor for open bite, whereas lingual thrust and contact of the tongue with the palatal rugae were protective
Grabowski et al. [49], Seemann et al. [50], and Stahl et al. [3]	3,041 German-speaking children: 1,496 ♀ and 1,545 ♂ 766 with primary dentition Mean age ± SD: 4.5 ± 0.9 years 2,275 with early mixed dentition Mean age ± SD: 8.3 ± 1.4 years	By 2 dentists and 2 orthodontists Elicitation of 8 words Assessment of /l/, /n/, /d/, /t/, and /s/ as physiological (/l/, /n/, /d/, /t/, and /s/), interdental (/l/, /n/, /d/, /t/, and /s/), addental (/s/), or lateral (/s/)	By 2 dentists and 2 orthodontists Sagittal occlusal relationship in the anterior and posterior region Transverse occlusal relationship in the posterior region Vertical occlusal relationship in the anterior region	Articulation disorders in 52.1% in AOB vs. 28% in normal occlusion ($p \leq 0.001$) Articulation disorders in 51.0% in crossbite vs. 28% in normal occlusion ($p \leq 0.001$) Articulation disorders in 16% in crowding vs. 21% in noncrowding ($p = 0.05$)
Van Lierde et al. [48]	110 Flemish-speaking children: 56 children referred to an orthodontist 32 ♀ and 24 ♂ Age 7–12 years (mean: 10.2) 54 children not referred to an orthodontist 29 ♀ and 25 ♂ Age 6–12 years (mean: 9.3)	By 2 SLP in consensus Picture-naming test (word level) Phonetic inventory Phonetic analysis Speech intelligibility	By 2 orthodontists Occlusion (angle) Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Phonetic disorders per child in 2.3 sounds in the orthodontic group vs. 1.92 in the nonorthodontic group ($p < 0.001$) Sigmatism in 59% of cases in the orthodontic group vs. 22% in the nonorthodontic group ($p < 0.001$) Phonetic disorder of /n/: 44% in the orthodontic group vs. 24% in the nonorthodontic group ($p = 0.028$) Lambdacism in 43% of cases in the orthodontic group vs. 19% in the nonorthodontic group ($p = 0.001$) Disorders of /t/ in 41% of cases in the orthodontic group vs. 13% in the nonorthodontic group ($p = 0.001$)

SLP, speech-language pathologist. [a] Examined the association between articulation and malocclusion exclusively.

Table 2. Overview of the articles discussing the association between biting habits and malocclusion

Study	Population	Biting habit assessment	Orthodontic assessment	Results
Chevitarese et al. [53]	112 Brazilian children 60 ♀ and 52 ♂ Age 4–6 years (mean ± SD: 61 ± 6.67 months)	Questions to the child	By a dentist Examination of teeth Occlusal plane Overjet Overbite Crossbite (anterior/posterior) Deep bite Open bite	Nail-biting was associated significantly with AOB ($p = 0.02$)
Gomes et al. [54]	764 Brazilian children 363 ♀ and 401♂ Age: 5 years	Parent questionnaire (pretested, nonvalidated)	By calibrated dentists Oral examinations AOB	AOB in 9.7% of the nail-biting group and 17.6% of the non-nail-biting group ($p = 0.007$)
Hebling et al. [55]	133 Brazilian children 68 ♀ and 65 ♂ Age: 5 years	Parent questionnaire (pretested, nonvalidated)	By calibrated examiners Dental Aesthetic Index Open bite Crossbite	AOB in 21% of the nail-biting group vs. 33% of the non-nail-biting group (nonsignificant) Crossbite in 13% of the nail-biting group vs. 17% of the non-nail-biting group (nonsignificant)
Urzal et al. [37]	568 Portuguese children 189 with primary dentition 88 ♀ and 101 ♂ Mean age ± SD: 5.39 ± 0.94 years 379 with mixed dentition 195 ♀ and 184 ♂ Mean age ± SD: 8.23 ± 0.99 years	By students (following training) Clinical evaluation (nail and lip biting)	By students (following training) AOB	No significant associations were found between biting habits and AOB
Van Lierde et al. [48]	110 Flemish-speaking children: 56 referred to an orthodontist 32 ♀ and 24 ♂ Age 7–12 years (mean: 10.2) 54 not referred to an orthodontist 29 ♀ and 25 ♂ Age 6–12 years (mean: 9.3)	Questionnaire (not pretested or validated)	By 2 orthodontists Angle classification Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Nail-biting habit in 32% of the orthodontic group vs. 31% of the nonorthodontic group (nonsignificant)

SLP, speech-language pathologist.

not validated or were completely based on patient or observer reports were considered "high risk." If not enough information was made available (e.g., not enough information about the intervention), the criterion was rated as "unclear." Further explanation of the criteria and how to assess them can be found in the paper by Munn et al. [45]. Studies were considered to be high risk and excluded for further analysis if the researchers deemed 3 or more criteria to be "high risk," as we aimed to only include studies with a low risk of bias. After quality assessment, the final 17 articles were retained. An overview of the number of articles included and excluded during each step can be found in Figure 1.

Data Extraction and Analysis

After screening, the following data were extracted from the remaining articles: author; year of publication; aim; number, age, and gender of the subjects; assessments performed; and results. These results were grouped according to the disorders considered in the population with malocclusions, i.e., AD, biting habits, bruxism, a low tongue position, and deviate swallowing. The data are summarized in Tables 1–5. No meta-analysis was performed on the remaining articles due to their heterogeneous methodologies.

Results

Quality and Risk-of-Bias Assessment

The quality of the 17 included articles is described in Table 6. The overall assessment of the quality of the included articles ranged from "unclear" (1 article) to "low" risk of bias (16 articles). Most frequently, studies were found to use assessments that were deemed to have a high risk of bias (9 articles). This was commonly caused by a lack of detail or because of the inclusion of only questionnaires or parent reports and no actual measurement for the diagnosis of OMD. Most of the questionnaires were self-made and nonvalidated. Moreover, 10 of the included articles did not provide sufficient information on the person who performed the examinations. In other cases, only dentists and orthodontists performed the assessments. Eight articles provided no information on how the sample size had been determined, resulting in "unclear" ratings of "adequate sample size." Finally, confounding variables that could have influenced the results, such as certain demographic factors or treatment history, were not accounted for in multiple articles.

Articulation and Malocclusion

Articulation and its relation to malocclusion was the sole emphasis of 1 article [47]. Another 4 articles considered the relation of articulation and malocclusion as 1 of multiple topics [3, 48–50]. Of these articles, 3 articles were part of 1 big, overarching longitudinal study [3, 49, 50]. All studies were deemed to have a low risk of bias. These studies are summarized in Table 1.

Table 3. Overview of the articles discussing the association between bruxism and malocclusion

Study	Population	Bruxism assessment	Orthodontic assessment	Results
Demir et al. [59][a]	965 Turkish children 493 ♀ *Mean age ± SD*: 12.7 ± 3.9 years 472 ♂ *Mean age ± SD*: 12.9 ± 4.1 years	Self-report Intraoral examination	Unclear who performed the assessment Angle classification Anterior crowding Crossbite (anterior/posterior) Open bite Deep bite Functional shift in occlusion Overjet	No statistically significant association existed between bruxism and occlusal factors
Ghafournia and Hajenourozali Tehrani [56][a]	400 Iranian children 51 children with bruxism 45.01% ♀ and 54.9% ♂ Age 3–6 years 349 children without bruxism	Parent questionnaire (not pretested or validated) Intraoral examination	By 1 examiner Canine and molar relationship Crossbite (anterior/posterior) Open bite Deep bite	Mesial step in 50% of the children with bruxism ($p = 0.001$) Flush terminal plane in 38% of the children with a flush terminal plane ($p = 0.023$)
Gomes et al. [54]	764 Brazilian children 363 ♀ and 401 ♂ Age 5 years	Parent questionnaire (pretested, nonvalidated)	By calibrated dentists Oral examinations AOB	AOB in 13% of the children with bruxism vs. 15% of the children without bruxism (nonsignificant)
Gonçalves et al. [60][a]	592 Brazilian children Age 4–16 years 255 children with bruxism 128 ♀ and 127 ♂ 337 controls 184 ♀ and 153 ♂	Questionnaire (not pretested or validated)	By 1 examiner Normal occlusion Crowding Crossbite Anterior open bite Anterior deep bite Overjet Angle classification	There was no relationship between the occlusal factors and bruxism
Nahás-Scocate et al. [57][a]	873 Brazilian children 434 ♀ and 439 ♂ Age 2 years and 1 month to 6 years and 11 months	Questionnaire (Junqueira et al. [88])	By 3 calibrated examiners Posterior crossbite	Bruxism in 17% of the children with crossbite vs. 30% of the children without crossbite ($p = 0.002$)
Sari and Sonmez [58][a]	394 Turkish children: Age 9–14 years 182 with mixed dentition 80 ♀ and 102 ♂ 212 with permanent dentition 114 ♀ and 98 ♂	Parent interview	Unclear who performed the assessment Angle classification Overjet Overbite Anterior and posterior crossbite Scissor bite Lateral open bite	In mixed dentition: Angle class I for first molar teeth in 78% of the bruxism group vs. 65% of the nonbruxism group ($p < 0.05$) Overjet >6 mm in 8% of the bruxism group vs. 0% of the nonbruxism group ($p < 0.01$) Overbite >5 mm in 8% of the bruxism group vs. 0% of the nonbruxism group ($p < 0.01$) Scissorbite in 17% of the bruxism group vs. 9% of the nonbruxism group ($p < 0.05$) Crossbite in 4% of the bruxism group vs. 0% of the nonbruxism group ($p < 0.01$). In permanent dentition: Overjet >6 mm in 6% of the bruxism group vs. 1% of the nonbruxism group ($p < 0.05$) Negative overjet in 6% of the bruxism group vs. 1% of the non-bruxism group ($p < 0.05$) Overbite>5 mm in 9% of the bruxism group vs. 1 % of the nonbruxism group ($p < 0.01$) AOB in 13% of the bruxism group vs. 0.5% of the nonbruxism group ($p < 0.01$)
Van Lierde et al. [59]	110 Flemish-speaking children: 56 referred to an orthodontist 32 ♀ and 24 ♂ Age 7–12 years (mean: 10.2) 54 not referred to an orthodontist 29 ♀ and 25 ♂ Age 6–12 years (mean: 9.3)	By 2 SLP in consensus Oromyofunctional examination Questionnaire (not pretested or validated)	By 2 orthodontists Angle classification Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Bruxism in 34% of the orthodontic group vs. 18% of the nonorthodontic group (nonsignificant)

SLP, speech-language pathologist. [a] Examined the association between articulation and malocclusion exclusively.

Botero-Mariaca et al. [47] compared 132 children with AOB to 132 children without AOB aged between 8 and 16 years. Using an articulation test, they found that significantly more children with AOB presented with distorted speech sounds, especially in the pronunciation of /t/, /s/, and /d/ [47]. Other articulation distortions, i.e., lingual interposition, lingual thrust, and tongue protrusion, were also more common in children with AOB. Contact with palatine rugae was significantly less common in children with AOB. Tongue contact with the palatine rugae and tongue protrusion were significantly related to the magnitude of the AOB [47].

Van Lierde et al. [48] reported data from 56 children who were referred to an orthodontist and 56 who were not, with ages between 7 and 12 years. Two speech-language pathologists made a phonetic inventory and analysis based on a picture-naming test. Children referred to orthodontic therapy showed significantly more AD. The disordered sounds were primarily alveolar, i.e., sigmatisms (i.e., phonetic disorders of /s/), more specifically

Table 4. Overview of the articles discussing the association between nonphysiological tongue position and malocclusion

Studies	Population	Low tongue position assessment	Orthodontic assessment	Results
Grabowski et al. [49], Seemann et al. [50], and Stahl et al. [3]	3,041 German-speaking children: 1,496 ♀ and 1,545 ♂ 766 with primary dentition *Mean age ± SD:* 4.5 ± 0.9 years 2,275 with early mixed dentition *Mean age ± SD:* 8.3 ± 1.4 years	By 2 dentists and 2 orthodontists Normal tongue posture Pathological tongue posture: interdental or caudal tongue position	By 2 dentists and two orthodontists Sagittal occlusal relationship in the anterior and posterior region Transverse occlusal relationship in posterior region Vertical occlusal relationship in anterior region	Unphysiological tongue posture in ±58% in overjet >4 mm vs. ±25% of overjet 0–2 mm ($p < 0.001$) Unphysiological tongue posture in 79.8% of AOB ($p < 0.001$) Unphysiological tongue posture in 74% of lateral crossbite ($p < 0.001$) Unphysiological tongue posture in 67.4% of increased overjet ($p < 0.001$) Unphysiological tongue posture in 46% of reduced overjet ($p < 0.001$)
Laganà et al. [62]	2,617 Albanian children 1,360 ♀ and 1,257 ♂ Age: 7–15 years	By 5 trained examiners Orthodontic evaluation Anamnestic questionnaire (not pretested or validated)	By 5 trained examiners Orthodontic examination (WHO guidelines)	Low tongue position did not show a significant correlation with any malocclusion characteristic
Van Lierde et al. [48]	110 Flemish-speaking children: 56 referred to an orthodontist 32 ♀ and 24 ♂ Age: 7–12 years, *mean:* 10.2 54 not referred to an orthodontist 29 ♀ and 25 ♂ Age: 6–12 years, *mean:* 9.3	By 2 SLP in consensus Oromyofunctional examination (Lembrechts et al. [89]) Questionnaire (not pretested or validated)	By 2 orthodontists Angle classification Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Severely impaired tongue function in 48% of the orthodontic group vs. 7% of the nonorthodontic group ($p < 0.001$) Decreased tongue function in 18% of the orthodontic group vs. 15% of the nonorthodontic group ($p < 0.001$) Anterior tongue position in 66% of the orthodontic group vs. 22% of the nonorthodontic group ($p < 0.001$)

SLP, speech-language pathologist.

sigmatism addentalis (i.e., the tongue tip rests on the central incisors during the production of /s/) and stridens (i.e., the /s/ sound contains a whistling sound). They also showed more disorders of /n/, as well as more lambdacisms (i.e., phonetic disorders of /l/), and more disorders of /t/, specifically addental production of /t/. However, no significant association was found between the type of malocclusion and the type of AD [48].

Grabowski et al. [49], Seemann et al. [50], and Stahl et al. [3] considered 766 children with primary dentition (average age 4.5 years), and 2,275 children with early mixed dentition (i.e., the stage where permanent teeth are erupting, while primary teeth are expelled [51]; average age 8.3 years). They only noted articulation of /l/, /n/, /d/, /t/, and /s/ and labelled the pronunciation of the sounds in accordance with Dieckman and Dieckman [52]. More AD were found in children with AOB and crossbite compared to those with normal occlusion. The authors found no correlations between specific malocclusions and AD [3]. However, in a later study, they found that children with crowding showed fewer AD [50].

Biting Habits and Malocclusion

Biting habits were only considered in articles discussing other OMD as well. Five articles exploring the link between biting habits and malocclusions were identified (Table 3) [37, 48, 53–55].

Chevitarese et al. [53] considered 112 children between 4 and 6 years of age and questioned them about their biting habits. They found a significant association between nail biting and AOB [53]. Gomes et al. [54] asked the parents of 764 five-year-old children to fill out a questionnaire that asked about biting habits, among other things. AOB was associated with less nail biting [54]. The biting habits of 133 five-year-old children were charted using a parent questionnaire by Hebling et al. [55]. No significant difference for nail biting was found in populations with and without AOB or with and without crossbite. Urzal et al. [37] examined 189 children with primary dentition (average age 5.39 years) and 379 children with mixed dentition (average age 8.23 years) for the presence of nail and lip biting. They found no association between lip or nail biting and AOB. Finally, the study of Van Lierde et al. [48], the population of which is described above, asked about biting habits in a questionnaire. They found that children referred to orthodontists and those not referred to orthodontists showed equal nail biting habits.

Bruxism and Malocclusion

The association between bruxism and malocclusion was discussed separately by 5 studies and it was one of the multiple parameters investigated in 2 studies, as depicted in Table 3 [48, 54, 56–60]. All of the studies were deemed to show a low risk of bias, except for the study of Sari and Sonmez [58], which was deemed to have an unclear level of bias. The found studies were inconclusive about the association between bruxism and malocclusion.

Three studies found associations between bruxism and different characteristics of malocclusion [56–58]. Ghafournia and Hajenourozali Tehrani [56] assessed bruxism

Table 5. Overview of the articles discussing the association between deviate swallowing and malocclusion

Studies	Population	Swallowing assessment	Orthodontic assessment	Results
Grabowski et al. [49], Seemann et al. [50], and Stahl et al. [3]	3,041 German-speaking children: 1,496 ♀ and 1,545 ♂ 766 with primary dentition *Mean age ± SD:* 4.5 ± 0.9 years 2,275 with early mixed dentition *Mean age ± SD:* 8.3 ± 1.4 years	By 2 dentists and 2 orthodontists Water and saliva swallowing (Garliner) Physiological swallowing Anterior interdental swallowing Bilateral interdental swallowing Total interdental swallowing	By 2 dentists and 2 orthodontists Sagittal occlusal relationship in the anterior and posterior regions Transverse occlusal relationship in the posterior region Vertical occlusal relationship in the anterior region	Visceral swallow in ±76% of overjet >4 mm vs. ±48% of overjet 0–2 mm ($p < 0.001$) Visceral swallow in 97% of children with AOB ($p < 0.001$) Visceral swallow in 60% of children with crowding vs. 65% of children without crowding ($p = 0.05$)
Hebling et al. [55]	133 Brazilian children 68 ♀ and 65 ♂ Age: 5 years	By calibrated examiners Recorded in accordance with the Brazilian Oral Health Epidemiological Survey (2002–2003)	By calibrated examiners Dental Aesthetic Index Open bite Crossbite	AOB in 61% of children with atypical swallow vs. 27% of children with typical swallow ($p < 0.001$) Crossbite in 27% of the children with atypical swallow vs. 16% of children with typical swallow ($p = 0.01$)
Kasparaviciene et al. [63]	503 Lithuanian children 243 ♀ and 260 ♂ *Mean age ± SD:* 5.95 ± 0.61 years	By 1 investigator Saliva swallowing	By 1 investigator Incisal segments (vertical overlap, AOB) Lateral segments (Angle classification) Transverse relation (normal, buccal crossbite, and lingual crossbite) Spacing	Children with infantile swallowing had a significantly higher prevalence of AOB ($p = 0.001$)
Lagana et al. [62]	2,617 Albanian children 1,360 ♀ and 1,257 ♂ Age: 7–15 years	By 5 trained examiners	By 5 trained examiners Orthodontic examination (WHO guidelines)	Atypical swallowing was significantly ($p = 0.01$) related with left and right canine malocclusion, left and right molar malocclusion, altered overjet, and AOB
Ovsenik [64]	243 Slovenian children 124 ♀ and 119 ♂ Examined at 3–5 years of age	Unclear who performed the assessment Saliva swallowing or small amounts of water Observation + palpation	Unclear who performed the assessement Posterior crossbite Midline deviation Transverse buccal relationships	Atypical swallowing in ±55% of children with and without crossbite (nonsignificant) The prevalence of deviate swallowing was not significantly different in children with and without crossbite; the prevalence of deviate swallowing increased over time in children with crossbite (±62%), while it decreased in children without crossbite (±35%)
Urzal et al. [37]	568 Portuguese children: 189 with primary dentition 88 ♀ and 101 ♂ *Mean age ± SD:* 5.39 ± 0.94 years 379 with mixed dentition 195 ♀ and 184 ♂ *Mean age ± SD:* 8.23 ± 0.99 years	By students (following training) Clinical examination	By students (following training) AOB	In both primary and mixed dentition, AOB was significantly associated with tongue thrusting ($p < 0.05$); in mixed dentition, tongue thrusting was found to be a risk factor for AOB
Van Lierde et al. [48]	110 Flemish-speaking children: 56 referred to an orthodontist 32 ♀ and 24 ♂ Age: 7–12 years, mean: 10.2 54 not referred to an orthodontist 29 ♀ and 25 ♂ Age: 6–12 years, mean: 9.3	Oromyofunctional examination (compare with Lembrechts et al. [89]) Swallowing: anterior interdental/addental tongue thrust, uni- or bilateral tongue thrust Questionnaire (not pretested or validated)	By 2 orthodontists Angle classification Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Impaired lip position during swallowing in 5% of the orthodontic group vs. 0% of the nonorthodontic group ($p = 0.006$) Tongue thrust swallow in 50% of the orthodontic group vs. 22% of the nonorthodontic group ($p = 0.03$) Tongue thrust swallowing and deep bite were associated ($p = 0.041$)

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through examination and self-report in 965 children between 3 and 6 years old. They found that mesial step (i.e., the distal surface of the mandibular deciduous second molar lies mesial to the maxillary one [61]), and a flush terminal plane (i.e., the distal surface of the mandibular deciduous second molar lies in the same vertical plane as the maxillary one [61]) were present more in children with bruxism [56]. Nahás-Scocate et al. [57] determined the presence of bruxism with a questionnaire in 873 children between 2 and 7 years of age. Less crossbite was found in children with bruxism [57]. Sari and Sonmez [58] considered 394 children between 9 and 14 years of age and relied on parent interviews to determine the presence of bruxism. In children with mixed dentition, they found that

Table 6. Overview of the quality assessment of the included articles

Study	Hypothesis described	Representative sample	Appropriate recruitment	Adequate sample size	Detailed sample and setting	Data analysis coverage	Valid assessments	Standard, reliable measures	Appropriate statistical analyses	Clear main findings	Confounding factors identified	Subpopulations identified objectively	Overall assessment
Botero-Mariaca et al. [47]	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Chevitarese et al. [53]	Low	Low	Low	Unclear	High	Low	High	Low	Low	Low	Unclear	Low	Low
Demir et al. [59]	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Unclear	Low	Low
Ghafournia and Hajenourozali Tehrani [56]	Low	Low	Low	Unclear	Low	Unclear	Low	Low	Low	Low	High	Low	Low
Gomes et al. [54]	Low	Low	Low	Low	Low	Low	Unclear	Low	Low	Low	Unclear	Low	Low
Gonçalves et al. [60]	Low	Low	Low	Unclear	Low	Low	Low	Low	Low	Low	High	Low	Low
Grabowski et al. [49], Stahl et al. [50], and Seemann et al. [3]	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Unclear	Low	Low
Hebling et al. [55]	Low	Low	Low	Low	Low	Low	Unclear	Low	Low	Low	Unclear	Low	Low
Kasparaviciene et al. [63]	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	High	Low	Low
Laganà et al. [62]	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	Unclear	Low	Low
Nahás-Scocate et al. [57]	Low	Low	Low	Unclear	Low	Low	High	Low	Low	Low	Low	Low	Low
Ovsenik [64]	Low	Low	Low	Unclear	Low	Low	High	Low	Low	Low	Unclear	Low	Low
Sari and Sonmez [58]	Low	Low	Low	Unclear	Low	Low	High	Unclear	Low	Low	Unclear	Low	Unclear
Urzal et al. [37]	Low	Low	Low	Unclear	Low	Low	High	Unclear	Low	Low	Unclear	Low	Low
Van Lierde et al. [48]	Low	Unclear	Low	Unclear	Low	Unclear	Low	Low	Low	Low	High	Low	Low

children with bruxism showed more Angle class I occlusion for first molar teeth, more overjet larger than 6 mm, more overbite larger than 5 mm, more scissor bite, and more crossbite for multiple teeth (anterior-posterior). In permanent dentition, overjet larger than 6 mm, negative overjet, overbite larger than 5 mm, and AOB were significantly more present in children with bruxism [58].

Four studies did not report any association between bruxism and malocclusion [48, 54, 59, 60]. Demir et al. [59] considered 965 children and adolescents between 7 and 19 years of age. They assessed bruxism with an intraoral examination and self-report, but they found no significant associations between bruxism and the considered occlusal factors. Gomes et al. [54] also included a question about bruxism in their questionnaire (see above) and found no significant relationship between bruxism and AOB. Gonçalves et al. [60] compared 255 children with bruxism between 4 and 16 years of age with 337 children without bruxism. They also used a questionnaire to assess bruxism and found no relationship between bruxism and occlusal factors. Similarly, Van Lierde et al. [48] found no difference in the presence of bruxism in an orthodontic treatment-seeking population versus the control population. They used oromyofunctional examinations and a questionnaire in their study [48].

Low Tongue Position and Malocclusion

No studies were performed that exclusively looked at the relationship between a low tongue position and malocclusion. Five selected studies, all with a low risk of bias, considered a low tongue position as one of the investigated parameters [3, 48–50, 62], and 3 of them were part of 1 big longitudinal study [3, 49, 50].

The population of the longitudinal study [3, 49, 50] has already been discussed above. They examined the children for their resting tongue position [3]. They found significantly more cases of an unphysiological tongue posture in children with an overjet larger than 4 mm [3]. They also found more cases of an unphysiological tongue position in children with AOB, with a lateral crossbite, with reduced overjet, and with increased overjet, all of which were significant relationships [49]. Crowding was not associated with the presence of a low tongue position (about 40% of the crowding and noncrowding groups) [50]. Van Lierde et al. [48] also considered tongue position in their oromyofunctional evaluation. They found a significantly impaired tongue function at rest in the orthodontic treatment-seeking population, as well as a more anterior tongue position compared to the non-treatment-seeking population. On the other hand, Laganà et al. [62] used an evaluation, as well as a questionnaire, to establish the tongue position in 2,617 children between 7 and 15 years of age. They did not find a significant correlation between a low tongue position and the considered malocclusal characteristics.

Deviate Swallowing and Malocclusion

Nine studies with multiple foci discussed the link between deviate swallowing and malocclusion and are summarized in Table 5 [3, 37, 48–50, 55, 62–64]. The 3 studies of the longitudinal research project will once again be discussed together [3, 49, 50]. In their population (discussed above), they categorized water and saliva swallows [3]. A visceral swallow pattern was significantly more present in children with overjet larger than 4 mm [3] and children with AOB [49]. Visceral swallowing was significantly less common in children with crowding [50]. Hebling et al. [55] assessed the swallow of 133 children following the Brazilian oral healthy epidemiological survey. Children presenting with an atypical swallow showed more AOB and crossbite compared to children with typical swallows [55]. Five hundred three children with a mean age of about 6 years were tested by Kasparaviciene et al. [63]. The investigators examined saliva swallows. They found that children with infantile swallowing had a significantly higher prevalence of AOB. Laganà et al. [62] assessed swallowing as well in their study (the population was discussed above). They found a significant association between atypical swallow and molar malocclusion, deviating overjet, and the presence of AOB ($p = 0.01$), with correlation sizes between 0.061 and 0.174.

Ovsenik [64] observed and palpated saliva and water swallows in 243 children examined at 3, 4, and 5 years of age. At 3 years of age, an equal prevalence of atypical swallowing was found in children with and without crossbite. However, the prevalence of atypical swallowing increased at 5 years of age in the group with crossbite, whereas the prevalence of atypical swallowing decreased over time in the group without crossbite. These trends were statistically significant ($p = 0.038$). The previously discussed population of Urzal et al. [37] was also clinically assessed for swallowing. They found a significant association between AOB and tongue thrust for both the group younger than 6 years and the group between 7 and 12 years of age. Finally, Van Lierde et al. [48] included swallowing in their oromyofunctional examination. The orthodontic therapy-seeking population presented with a more decreased function for the lip position during swallowing, which was not found in the non-treatment-seeking group, and more tongue thrust swallowing [48]. Moreover, a significant relationship between a deep bite and tongue thrust was found [48].

Discussion

The aim of this systematic review was to explore the reported relationships between malocclusions, OMD, and AD in children and adolescents between 3 and 18 years of age. A possible relationship between AOB and AD, between malocclusions and disorders of the apico-alveolar sounds, and between AOB and deviate swallowing was found. For biting habits, bruxism, a low tongue position, and deviate swallowing, no clear conclusions could be drawn based on the included articles.

This review found that, despite the multitude of articles on OMD, AD, and malocclusions, articles that considered a possible link between OMD, AD, and malocclusions were more uncommon. Most of the included articles represented evidence levels 3 and 4 [65]. Moreover, only a minority of the included studies were longitudinal, which would be the most ideal study design for discovering associations during development [39]. Frequently, OMD and AD were studied within one article, without a clear focus on one particular disorder [3, 48, 62]. Even though investigating multiple disorders at the same time may not provide as much detail, it is a more accurate representation of reality. Often, multiple OMD and malocclusion traits were present at the same time, e.g., deviate swallowing and pacifier habit, AOB, and crossbite [66]. Moreover, OMD and AD could influence one another as well [67–69]. For example, it was reported that AD improve after orofacial myofunctional therapy, showing that OMD could influence articulation [69, 70]. Furthermore, other variables, such as restriction of the nasal passage, have been implicated to cause other OMD and thus are inherently related [71]. It was, therefore, likely not optimal to consider OMD and AD separately, especially given that both of these disorders present with a high prevalence in children [3, 4, 18]. Describing the relationship between OMD and AD is essential to inform optimal treatment. Nevertheless, the current review evaluated each OMD disorder separately due to the nature of our research question and the included articles, which also separated the different OMD. This can be seen as a limitation of the current review. Future research could consider interrelationships between: (1) different OMD, (2) OMD and AD, and (3) OMD, AD, and malocclusion.

The common denominator in the included articles was variability. Populations were recruited in different settings (e.g., schools or orthodontic centers) or described and compared using different characteristics (e.g., the presence of AOB or being referred to an orthodontic center), all of which influenced the results. Variable terminology and assessments were used for both malocclusion and OMD. Often, different terminologies were used to denominate the same concept, e.g., deviate swallowing, visceral swallowing, and tongue thrust could all refer to the same OMD, as has been noted before in the literature [6]. Conversely, even when the same terminology was used, the concepts behind them were not necessarily the same. For example, for AOB, some studies did not provide a definition [37] and other studies did provide the used definition [54], whereas different studies provided a quantification of the characteristic [47]. These issues were apparent throughout all articles. Assessments were diverse among the articles as well. For malocclusions, the most commonly used classification was the Angle classification [72], despite the critiques of this particular classification [73, 74]. There was no uniformity in the methodology or classification of AD [3, 47]. Bruxism, on the other hand, was considered as present in some studies based on a questionnaire [57] or a different questionnaire and a clinical examination [56]. Moreover, the results were described variably, presumably because of the variety of research questions. Some studies included frequency tables along with their significance values [48], and some only presented significance values for certain aspects of their research [62]. None of the studies reported effect sizes, only the significance level of the results. The described inconsistency in reporting made it difficult to compare the results of one study with those of another.

Another common trait across the included studies was the use of questionnaires and parent report questionnaires to assess OMD [54, 55, 60]. While self-report on a population level could be valid [40], some caution in interpreting the results would be appropriate due to the possibility of bias. As children were the population of interest, questionnaires were often filled out by parents or guardians. Kasparaviciene et al. [63] found a disagreement rate as high as 28.5% between the parent report and the clinical observation. Therefore, to be truly valid, questionnaires should be combined with clinical examinations rather than solely relying on questionnaires, as was often the case.

Finally, all but 3 articles included in this review were published in journals focusing on dentistry. None of the included articles were published in journals focusing on speech-language pathology, while this was not an exclusion criterion. Possibly, the angle taken in the current review, looking at the relationship between malocclusions, OMD, and/or AD, caused this discrepancy. While these questions should warrant a multidisciplinary approach, there still was an emphasis on malocclusion. Another possible explanation could be that, while oromyofunctional therapy has existed for several years, its effectiveness was questioned until the American Speech-Language-Hearing Association revised its position in 1990 [75].

Quality control of the articles revealed that not all confounding variables were taken into account when discussing the results. However, within the studies included in this review, Stahl et al. [3] found gender differences for some oral habits, as did Laganà et al. [62]. On the other hand, Gonçalves et al. [60] found no gender difference for the prevalence of malocclusion. As the exact gender disparities for malocclusion, OMD, and AD are not yet clear, gender should be taken into account when analyzing data on malocclusion, OMD, and AD. Differences in malocclusion depending on ethnicity were described in malocclusions [76–78] but they were described in only 1 article included in this review [57]. Similarly, a history of speech-language therapy was only mentioned in 2 studies [47, 57], while speech-language therapy could improve dentofacial disorders, especially in combination with orthodontia [32]. Both studies chose to exclude children with a history of speech-language therapy to avoid bias. To summarize, in most of the included articles, not every important bias or confounding variables were considered.

Lastly, 3 studies focused on only 1 malocclusion in particular, i.e., AOB [37, 47, 54]. AOB might receive more attention compared to other malocclusions because of its difficult treatment [37, 47]. Frequently, the correction of AOB does not remained stable, leading to relapse [47]. Furthermore, in this review, it became apparent that some OMD and AD appeared to be related to AOB.

When looking at the specific subcategories of malocclusion, some observations could be made as well. AD were the only disorder to be consistently tested with an actual assessment. However, the description of the articulation assessment was often lacking details, e.g., not mentioning how the sounds were elicited or if words or sentences were pronounced, or the assessment was not performed by a speech-language pathologist. The available evidence implied a connection between articulation and malocclusion, regardless of the age of the children. Despite differences in methodology, all of the studies found more AD in children with malocclusion about 50% of the time. Malocclusions were associated with alveolar AD, specifically alveolar stops and fricatives [3, 47, 48], which was similar to previously reported studies [19]. Furthermore, AOB was the most common malocclusion associated with AD [47–49]. AOB can change the articulatory surface and often cooccurs with skeletal abnormalities leading to “long-face syndrome” [79]. The exact nature of the cooccurrence of malocclusions and AD (causal vs. compensatory) remains to be elucidated.

On biting habits, on the other hand, this review could not provide conclusive findings, though none of the studies focused solely on biting habits. While 1 study found a significant relationship between nail biting and AOB [53], Gomes et al. [54] found less AOB in a similarly aged population that bit their nails. The other studies with similar or slightly older populations did not find a connection at all [37, 48, 55]. A possible explanation for these inconclusive results could be that biting habits are more diverse and more transient than, for example, nonnutritive sucking habits, upon which the literature has extensively focused. It is thought that mainly constant forces, and not transient ones, cause teeth to move [12, 13]. Furthermore, the presence of biting habits was verified in only 1 with a clinical examination; the other studies relied on self-reports. Biting habits could be considered body-focused repetitive behavior, as could sucking habits [8]. Some studies also associated the presence of biting habits with that of sucking habits [7, 80]. More literature is available on the association between sucking habits and malocclusion, as evidenced by the above described systematic reviews [33, 36]. These reviews found that children who presented with sucking habits similarly had more malocclusions traits (e.g., crossbite and AOB) [33, 34]. Given the previously discussed similarity between biting and sucking habits, similar relationships between biting habits and malocclusal traits could be hypothesized. However, this review found only some evidence to support this notion.

Similarly, for the link between malocclusion and bruxism, the included studies were inconclusive within this systematic review. The variations between the articles could be explained by different definitions of bruxism, or different included age groups, though no pattern emerged. Half of the studies found associations between bruxism and malocclusion traits in children between 3 and 14 years of age, i.e., a flush terminal plane and mesial step [56], less crossbite [57], differences in overjet, overbite, open bite, and crossbite [58]. The other 4 articles found no such associations, but more of these studies considered older populations. Therefore, no conclusion could be drawn about the exact influence of bruxism on malocclusion, though there appears to be a possible effect of bruxism on malocclusion, especially in younger children. Lobbezoo et al. [81] wrote a systematic review on (mal) occlusion and bruxism in a population not restricted for age. They found no evidence that malocclusion causes bruxism. On the other hand, bruxism might adversely influence the masticatory system, resulting in injury, tooth wear, or disorders of the temporomandibular joint [81–83].

There appeared to be some connections between a low physiological tongue position and malocclusal factors [48]. Relationships of a low tongue position with deviating overjet, AOB, and crossbite were suggested [3, 49]. However, 1 study found no connection at all [62]. The tongue has often been implicated in the occurrence of malocclusions [84]. Low tongue postures have been connected to multiple malocclusions, such as class III malocclusion [85], crossbite [86], and AOB [87]. It is likely due to the paucity of studies that considered a low tongue position as a separate entity, which was required in this study, that the current review did not find any connections.

On the other hand, deviate swallowing in malocclusions was commonly described. The included studies often indicated the cooccurrence of deviate swallowing and AOB, with often more than half of the children with deviate swallow presenting with AOB [37, 49, 55, 62, 63]. This appeared to be the most prevalent connection between an OMD and malocclusion found in this review. This is supported by the literature, that has already described this connection previously [6]. However, according to some theories, deviant swallowing would exert a strong force but short-duration pressure, which typically does not influence occlusion [12–14]. On the other hand, deviant swallowing could persist due to the presence of other OMD such as sucking behavior or low resting tongue postures [64]. It was also suggested that deviate swallowing could also be considered an opportunistic or compensatory behavior [14, 15]. Furthermore, AOB was almost always measured and included in the parameters, whereas other occlusal parameters were not, which could be a possible bias in the literature. Crossbite appeared to be a second malocclusal factor associated with deviate swallowing, possibly more so in older age groups [55, 64]. However, less evidence supported this association.

To summarize, there were only a few high-quality articles that linked OMD, AD, and malocclusion. Children with malocclusion, specifically AOB, presented with more AD of alveolar stops and fricatives. Children with AOB also seemed to demonstrate more deviate swallowing. Other associations were difficult to discern due to the limited studies included as well as heterogeneity in methodology and definitions. Therefore, there is a need for evidence from level 1 and 2 studies [65] on the relationship between malocclusion and both OMD and AD. The literature would benefit from high-quality studies focused on specific OMD, AD, and/or malocclusion, controlling for the nonstudied OMD. Broader studies looking at how OMD and AD themselves are interrelated would also provide useful information. As of right now, there is no standardized way to measure OMD, AD, and malocclusions. Developing a more consistent terminology and methodology for the assessment of malocclusion, AD, and OMD across disciplines can be beneficial. It will facilitate comparing separate studies and combining evidence in, for example, a meta-analysis. Moreover, it can improve communication and collaboration between the different disciplines involved in the diagnosis and treatment of malocclusions, AD, and OMD. Longitudinal studies deliver a higher level of evidence compared to cross-sectional studies and are more appropriate for the study of associations during the development of malocclusion [40]. Therefore, there is a need for more qualitative, scientifically sound research on the prevalence of OMD and AD with malocclusions.

Conclusion

While plenty of articles discussing OMD, AD, and malocclusion were available, only a few articles were high quality. This systematic review found that AD and nonphysiological swallowing may often cooccur with an AOB. Malocclusion also was associated with apico-alveolar AD. On the other hand, biting habits did not appear to be related to malocclusions. For the other habits, bruxism, and a low tongue position at rest, there was not enough concurring evidence to support a similar connection. More high-quality, longitudinal research is needed to shed more light on OMD and AD along with malocclusions.

Conflict of Interest Statement

The authors have no conflict of interests to declare.

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Author Contributions

Z.T. contributed to the conception of the topic, data collection and extraction, data analysis, and the drafting of this paper. L.B. also contributed to data collection and extraction and data analysis and critically revised this paper. G.D.P. worked on the conception of the topic and critical revision. K.M.V.L. was part of the conception of the topic, supervision of the data collection and analysis, and critical revision of this work.

References

1 Felício CM, Ferreira CL. Protocol of orofacial myofunctional evaluation with scores. Int J Pediatr Otorhinolaryngol. 2008 Mar;72(3):367–75.

2 D'Onofrio L. Oral dysfunction as a cause of malocclusion. Orthod Craniofac Res. 2019 May;22(Suppl 1):43–8.

3 Stahl F, Grabowski R, Gaebel M, Kundt G. Relationship between occlusal findings and orofacial myofunctional status in primary and mixed dentition. Part II: prevalence of orofacial dysfunctions. J Orofac Orthop. 2007 Mar;68(2):74–90.

4 Wadsworth SD, Maul CA, Stevens EJ. The prevalence of orofacial myofunctional disorders among children identified with speech and language disorders in grades kindergarten through six. Int J Orofacial Myology. 1998;24:1–19.

5 Lobbezoo F, Ahlberg J, Glaros AG, Kato T, Koyano K, Lavigne GJ, et al. Bruxism defined and graded: an international consensus. J Oral Rehabil. 2013 Jan;40(1):2–4.

6 Mason RM, Proffit WR. The tongue thrust controversy: background and recommendations. J Speech Hear Disord. 1974 May;39(2):115–32.

7 Thomaz EB, Cangussu MC, Assis AM. Malocclusion and deleterious oral habits among adolescents in a developing area in northeastern Brazil. Braz Oral Res. 2013 Jan-Feb;27(1):62–9.

8 Woods DW, Houghton DC. Evidence-Based Psychosocial Treatments for Pediatric Body-Focused Repetitive Behavior Disorders. J Clin Child Adolesc Psychol. 2016;45(3):227–40.

9 Peres KG, Cascaes AM, Nascimento GG, Victora CG. Effect of breastfeeding on malocclusions: a systematic review and meta-analysis. Acta Paediatr. 2015 Dec;104(467):54–61.

10 Shenoy RP, Shenoy-Panchmal G. Dentofacial abnormalities among adolescents: A study on the prevalence and severity. J Clin Exp Dent. 2015 Apr;7(2):e273–7.

11 Ocampo-Parra A, Escobar-Toro B, Sierra-Alzate V, Rueda ZV, Lema MC. Prevalence of dyslalias in 8 to 16 year-old students with anterior open bite in the municipality of Envigado, Colombia. BMC Oral Health. 2015 Jul;15(1):77.

12 Mew JR. The postural basis of malocclusion: a philosophical overview. Am J Orthod Dentofacial Orthop. 2004 Dec;126(6):729–38.

13 Proffit WR. Equilibrium theory revisited: factors influencing position of the teeth. Angle Orthod. 1978 Jul;48(3):175–86.

14 Mason RM. Myths that persist about orofacial myology. Int J Orofacial Myology. 2011 Nov;37:26–38.

15 Kurihara K, Fukui T, Sakaue K, Hori K, Ono T, Saito I. The effect of tongue thrusting on tongue pressure production during swallowing in adult anterior open bite cases. J Oral Rehabil. 2019 Oct;46(10):895–902.

16 Lavigne GJ, Khoury S, Abe S, Yamaguchi T, Raphael K. Bruxism physiology and pathology: An overview for clinicians. J Oral Rehabil. 2008 Jul;35(7):476–94.

17 Bunton K, Huber JE. Articulation and resonance. In: Rousseau B, Branski RC, editors. Anatomy and physiology of speech and hearing. New York: Thieme; 2018. pp. 391–441.

18 American Speech-Language-Hearing Association. Speech sound disorders: articulation and phonology [Internet] [cited 2020 Apr 13]. Available from: https://www.asha.org/Practice-Portal/Clinical-Topics/Articulation-and-Phonology/.

19 Johnson NC, Sandy JR. Tooth position and speech—is there a relationship? Angle Orthod. 1999 Aug;69(4):306–10.

20 Hyde A, Moriarty L, Morgan A, Elsharkasi L, Deery C. Speech and the dental interface. Pediatr Dent. 2018;45(9):795–803.

21 Mason KN. The Effect of Dental and Occlusal Anomalies on Articulation in Individuals With Cleft Lip and/or Cleft Palate. Perspect ASHA Spec Interest Groups. 2020;5(6):1492–504.

22 Leavy KM, Cisneros GJ, LeBlanc EM. Malocclusion and its relationship to speech sound production: redefining the effect of malocclusal traits on sound production. Am J Orthod Dentofacial Orthop. 2016 Jul;150(1):116–23.

23 Tibolla C, Rigo L, Nojima LI, Estacia A, Frizzo EG, Lodi L. Association between anterior open bite and pacifier sucking habit in schoolchildren in a city of southern Brazil. Dental Press J Orthod. 2013;17(6):89–96.

24 Lopes Freire GM, Espasa Suarez de Deza JE, Rodrigues da Silva IC, Butini Oliveira L, Ustrell Torrent JM, Boj Quesada JR. Non-nutritive sucking habits and their effects on the occlusion in the deciduous dentition in children. Eur J Paediatr Dent. 2016 Dec;17(4):301–6.

25 Benson PE, Javidi H, DiBiase AT. What is the value of orthodontic treatment? Br Dent J. 2015 Feb;218(3):185–90.

26 Zhang M, McGrath C, Hägg U. The impact of malocclusion and its treatment on quality of life: a literature review. Int J Paediatr Dent. 2006 Nov;16(6):381–7.

27 Banabilh SM. Orthodontic view in the diagnoses of obstructive sleep apnea. J Orthod Sci. 2017 Jul-Sep;6(3):81–5.

28 Al Lawati NM, Patel SR, Ayas NT. Epidemiology, risk factors, and consequences of obstructive sleep apnea and short sleep duration. Prog Cardiovasc Dis. 2009 Jan-Feb;51(4):285–93.

29 Blechner M, Williamson AA. Consequences of Obstructive Sleep Apnea in Children. Curr Probl Pediatr Adolesc Health Care. 2016 Jan;46(1):19–26.

30 Richmond S, Dunstan F, Phillips C, Daniels C, Durning P, Leahy F. Measuring the cost, effectiveness, and cost-effectiveness of orthodontic care. World J Orthod. 2005;6(2):161–70.

31 American Speech-Language-Hearing Association. Scope of practice in speech-language pathology [Internet]. 2016 [cited 2019 Feb 17]. Available from: www.asha.org/policy.

32 Homem MA, Vieira-Andrade RG, Falci SG, Ramos-Jorge ML, Marques LS. Effectiveness of orofacial myofunctional therapy in orthodontic patients: a systematic review. Dental Press J Orthod. 2014 Jul-Aug;19(4):94–9.

33 Doğramacı EJ, Rossi-Fedele G. Establishing the association between nonnutritive sucking behavior and malocclusions: A systematic review and meta-analysis. J Am Dent Assoc. 2016 Dec;147(12):926–34.e6.

34 Schmid KM, Kugler R, Nalabothu P, Bosch C, Verna C. The effect of pacifier sucking on orofacial structures: a systematic literature review. Prog Orthod. 2018 Mar;19(1):8.

35 Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016 Oct;355:i4919.

36 Fraga WS, Seixas VM, Santos JC, Paranhos LR, César CP. Mouth breathing in children and its impact in dental malocclusion: a systematic review of observational studies. Minerva Stomatol. 2018 Jun;67(3):129–38.

37 Urzal V, Braga AC, Ferreira AP. The prevalence of anterior open bite in Portuguese children during deciduous and mixed dentition – correlations for a prevention strategy. Int Orthod. 2013 Mar;11(1):93–103.

38 Góis EG, Ribeiro-Júnior HC, Vale MP, Paiva SM, Serra-Negra JM, Ramos-Jorge ML, et al. Influence of nonnutritive sucking habits, breathing pattern and adenoid size on the development of malocclusion. Angle Orthod. 2008 Jul;78(4):647–54.

39 Dimberg L, Lennartsson B, Söderfeldt B, Bondemark L. Malocclusions in children at 3 and 7 years of age: a longitudinal study. Eur J Orthod. 2013 Feb;35(1):131–7.

40 Dimberg L, Lennartsson B, Arnrup K, Bondemark L. Prevalence and change of malocclusions from primary to early permanent dentition: a longitudinal study. Angle Orthod. 2015 Sep;85(5):728–34.

41 Tausche E, Luck O, Harzer W. Prevalence of malocclusions in the early mixed dentition and orthodontic treatment need. Eur J Orthod. 2004 Jun;26(3):237–44.

42 Van Dyck C, Dekeyser A, Vantricht E, Manders E, Goeleven A, Fieuws S, et al. The effect of orofacial myofunctional treatment in children with anterior open bite and tongue dysfunction: a pilot study. Eur J Orthod. 2016 Jun;38(3):227–34.

43 Carels C, De Ridder L, Van Loock N, Bogaerts K, Eyssen M, Obyn C. Orthodontie bij kinderen en adolescenten [Internet]. Brussels: Federaal Kenniscentrum voor de Gezondheidszorg (KCE); 2008 [cited 2021 Jan 31]. Available from: http://www.kce.fgov.be.

44 Willems G, De Bruyne I, Verdonck A, Fieuws S, Carels C. Prevalence of dentofacial characteristics in a Belgian orthodontic population. Clin Oral Investig. 2001 Dec;5(4):220–6.

45 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 Aug;3(3):123–8.
46 Genaidy AM, Lemasters GK, Lockey J, Succop P, Deddens J, Sobeih T, et al. An epidemiological appraisal instrument – a tool for evaluation of epidemiological studies. Ergonomics. 2007 Jun;50(6):920–60.
47 Botero-Mariaca P, Sierra-Alzate V, Rueda ZV, Gonzalez D. Lingual function in children with anterior open bite: A case-control study. Int Orthod. 2018 Dec;16(4):733–43.
48 Van Lierde KM, Luyten A, D'haeseleer E, Van Maele G, Becue L, Fonteyne E, et al. Articulation and oromyofunctional behavior in children seeking orthodontic treatment. Oral Dis. 2015 May;21(4):483–92.
49 Grabowski R, Kundt G, Stahl F. Interrelation between occlusal findings and orofacial myofunctional status in primary and mixed dentition. Part III. Interrelation between malocclusions and orofacial dysfunctions. J Orofac Orthop. 2007 Nov;68(6):462–76.
50 Seemann J, Kundt G, Stahl de Castrillon F. Relationship between occlusal findings and orofacial myofunctional status in primary and mixed dentition. Part IV. Interrelation between space conditions and orofacial dysfunctions. J Orofac Orthop. 2011 Mar;72(1):21–32.
51 Lynch RJM. The primary and mixed dentition, post-eruptive enamel maturation and dental caries: a review. Int Dent J. 2013 Dec;63:3–13.
52 Dieckmann O, Dieckmann A. Logopädischer Befundbogen. Rostock: Universität Rostock; 1990.
53 Chevitarese AB, Della Valle D, Moreira TC. Prevalence of malocclusion in 4-6 year old Brazilian children. J Clin Pediatr Dent. 2002;27(1):81–5.
54 Gomes MC, Neves ÉT, Perazzo MF, Martins CC, Paiva SM, Granville-Garcia AF. Association between psychological factors, socio-demographic conditions, oral habits and anterior open bite in five-year-old children. Acta Odontol Scand. 2018 Nov;76(8):553–8.
55 Hebling SR, Cortellazzi KL, Tagliaferro EP, Hebling E, Ambrosano GM, Meneghim MC, et al. Relationship between malocclusion and behavioral, demographic and socioeconomic variables: a cross-sectional study of 5-year-olds. J Clin Pediatr Dent. 2008;33(1):75–9.
56 Ghafournia M, Hajenourozali Tehrani M. Relationship between Bruxism and Malocclusion among Preschool Children in Isfahan. J Dent Res Dent Clin Dent Prospects. 2012;6(4):138–42.
57 Nahás-Scocate AC, Coelho FV, de Almeida VC. Bruxism in children and transverse plane of occlusion: is there a relationship or not? Dental Press J Orthod. 2014 Sep-Oct;19(5):67–73.
58 Sari S, Sonmez H. The relationship between occlusal factors and bruxism in permanent and mixed dentition in Turkish children. J Clin Pediatr Dent. 2001;25(3):191–4.
59 Demir A, Uysal T, Guray E, Basciftci FA. The relationship between bruxism and occlusal factors among seven- to 19-year-old Turkish children. Angle Orthod. 2004 Oct;74(5):672–6.
60 Gonçalves LP, de Toledo OA, Otero SA. The relationship between bruxism, occlusal factors and oral habits. Dental Press J Orthod. 2010;15(2):97–104.
61 Farsi NM, Salama FS. Characteristics of primary dentition occlusion in a group of Saudi children. Int J Paediatr Dent. 1996 Dec;6(4):253–9.
62 Laganà G, Fabi F, Abazi Y, Beshiri Nastasi E, Vinjolli F, Cozza P. Oral habits in a population of Albanian growing subjects. Eur J Paediatr Dent. 2013 Dec;14(4):309–13.
63 Kasparaviciene K, Sidlauskas A, Zasciurinskiene E, Vasiliauskas A, Juodzbalys G, Sidlauskas M, et al. The prevalence of malocclusion and oral habits among 5-7-year-old children. Med Sci Monit. 2014 Oct;20:2036–42.
64 Ovsenik M. Incorrect orofacial functions until 5 years of age and their association with posterior crossbite. Am J Orthod Dentofacial Orthop. 2009 Sep;136(3):375–81.
65 OCEBM Levels of Evidence Working Group. The Oxford Levels of Evidence 2 [Internet]. 2011. Available from: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence.
66 Nihi VS, Maciel SM, Jarrus ME, Nihi FM, Salles CL, Pascotto RC, et al. Pacifier-sucking habit duration and frequency on occlusal and myofunctional alterations in preschool children. Braz Oral Res. 2015;29(1):1–7.
67 Rohrbach S, Buettner F, Pollex D, Mathmann P, Weinhold L, Schubert R, et al. Quantitative examination of isometric tongue protrusion forces in children with oro-facial dysfunctions or myofunctional disorders. J Oral Rehabil. 2018 Mar;45(3):228–34.
68 Bigenzahn W, Fischman L, Mayrhofer-Krammel U. Myofunctional therapy in patients with orofacial dysfunctions affecting speech. Folia Phoniatr (Basel). 1992;44(5):238–44.
69 Umberger FG, Johnston RG. The efficacy of oral myofunctional and coarticulation therapy. Int J Orofacial Myology. 1997;23:3–9.
70 Ray J. Effects of orofacial myofunctional therapy on speech intelligibility in individuals with persistent articulatory impairments. Int J Orofacial Myology. 2003 Nov;29(1):5–14.
71 Mason RM. A retrospective and prospective view of orofacial myology. Int J Orofacial Myology. 2005 Nov;31:5–14.
72 Angle EH. Classification of Malocclusion. Dent Cosmos. 1899;41:248–64.
73 Du SQ, Rinchuse DJ, Zullo TG, Rinchuse DJ. Reliability of three methods of occlusion classification. Am J Orthod Dentofacial Orthop. 1998 Apr;113(4):463–70.
74 Rinchuse DJ, Rinchuse DJ. Ambiguities of Angle's classification. Angle Orthod. 1989;59(4):295–8.
75 Erskine B. Orofacial Myology: National and International Perspectives. Perspect Glob Issues Commun Sci Relat Disord. 2015;5(2):82–96.
76 Trottman A, Elsbach HG. Comparison of malocclusion in preschool black and white children. Am J Orthod Dentofacial Orthop. 1996 Jul;110(1):69–72.
77 Johe RS, Steinhart T, Sado N, Greenberg B, Jing S. Intermaxillary tooth-size discrepancies in different sexes, malocclusion groups, and ethnicities. Am J Orthod Dentofacial Orthop. 2010 Nov;138(5):599–607.
78 Rebouças AG, Zanin L, Ambrosano GM, Flório FM. Fatores individuais associados à má oclusão em adolescentes. Cien Saude Colet. 2017 Nov;22(11):3723–32.
79 Ngan P, Fields HW. Open bite: a review of etiology and management. Pediatr Dent. 1997 Mar-Apr;19(2):91–8.
80 Leung AK, Robson WL. Nailbiting. Clin Pediatr (Phila). 1990 Dec;29(12):690–2.
81 Lobbezoo F, Ahlberg J, Manfredini D, Winocur E. Are bruxism and the bite causally related? J Oral Rehabil. 2012 Jul;39(7):489–501.
82 Veiga N, Angelo T, Ribeiro O, Baptista A. Bruxism: a literature review. Int J Dent Oral Health. 2015;1(3).
83 Manfredini D, Colonna A, Bracci A, Lobbezoo F. Bruxism: a summary of current knowledge on aetiology, assessment and management. Oral Surg. 2020;13(4):358–70.
84 Mew J. The influence of the tongue on dentofacial growth. Angle Orthod. 2015 Jul;85(4):715–6.
85 Primozic J, Farčnik F, Perinetti G, Richmond S, Ovsenik M. The association of tongue posture with the dentoalveolar maxillary and mandibular morphology in Class III malocclusion: a controlled study. Eur J Orthod. 2013 Jun;35(3):388–93.
86 Volk J, Kadivec M, Mušič MM, Ovsenik M. Three-dimensional ultrasound diagnostics of tongue posture in children with unilateral posterior crossbite. Am J Orthod Dentofacial Orthop. 2010 Nov;138(5):608–12.
87 Kravanja SL, Hocevar-Boltezar I, Music MM, Jarc A, Verdenik I, Ovsenik M. Three-dimensional ultrasound evaluation of tongue posture and its impact on articulation disorders in preschool children with anterior open bite. Radiol Oncol. 2018 Sep;52(3):250–6.
88 Junqueira TH, Nahás-Scocate AC, Valle-Corotti KM, Conti AC, Trevisan S. Association of infantile bruxism and the terminal relationships of the primary second molars. Braz Oral Res. 2013 Jan-Feb;27(1):42–7.
89 Lembrechts D, Verschueren D, Heulens H, Valkenburg HA, Feenstra L. Effect of a logopedic instruction program after adenoidectomy on open mouth posture: a single-blind study. Folia Phoniatr Logop. 1999;51(3):117–23.