Review Article

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

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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 between 3 and 18 years old. To conduct a systematic review, four 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 Munn, Moola, Riitano, and Lisy's (2014) tool in consensus. Using the search strategy, the authors identified 2652 articles after the removal of duplicates. After reviewing the eligibility criteria, 17 articles were included in the study. One of the included articles was deemed to have an unclear risk of bias, whereas all other articles were considered 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 co-occurrence 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, oropharynx) that affect oral posture and functions negatively [1,2]. Orofacial myofunctional disorders are said to be present in 48% of the population and their prevalence is even higher 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. Mew's [12] "tropic premise" hypothesizes that teeth and jaw position are not only determined by genetics but are also guided by oral posture. This means that OMD, such as low tongue position, could negatively impact facial and dental development. While dental structures have proven 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 the teeth, such as 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 effect on the dentition and occlusion [13]. However, while most of these theories are based on 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 three dimensions: voicing, manner, and place of production [17]. It is estimated that 2-24% of the school-aged children present with some kind of articulation disorder [18]. Correlations between malocclusions and articulation disorders (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 to the occlusion and dental morphology are related to specific AD [21]. In non-cleft palate populations as well, AD are found to co-occur with malocclusions [20,22]. Especially sibilant sounds 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 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 both direct costs (e.g., material cost, transport cost), 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 non-nutritive 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 non-nutritive sucking disorder persisted, the bigger the risk for malocclusion was [33]. Another systematic review by Schmid et al. looked specifically at pacifier sucking and its effect on orofacial structures [34] 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 non-randomized 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 moderate to low quality. Nevertheless, OMD do not comprise 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 show high prevalences in children [3,4,18] and starting from about 3 years of age, the negative effects of sucking habits become apparent in the primary dentition [37]. The occlusion in the primary dentition is of importance as it guides the 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, maxilla, and dental arch [41]. Similarly, there is some research indicating the benefits of the 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 treatment taking place between 6 and 18 years of age [43,44]. Therefore, the group of children and adolescents between 3 and 18 years old were 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 if OMD and/or AD are 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 old, who have a malocclusion, compared with those without a malocclusion, at greater risk for OMD (bruxism, deviate swallowing, caudal resting tongue posture, biting habits) and/or AD?

Methods

The research question was addressed using a systematic review. Before the onset of the review, the protocol was designed and registered in Prospero (PROPSPERO 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 the review were children and adolescents between 3 and 18 years old 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 with the malocclusion and OMD/articulation disorder. The studies needed to use questionnaires, or examinations to determine 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 the review.

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

Identification of Studies

Based on the described inclusion and exclusion criteria, a search strategy was determined. The used search strategy and search terms consisted of three parts. The first part described the population: children and adolescents. These search terms were used along with common synonyms (e.g., youth, teenager) and database-specific search terms. The second part, connected to the first part with an "AND" connection, 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 two with "AND", defined the OMD and AD, in two different parts. The following terms were used for OMD: orofacial myofunctional disorders, swallowing, open mouth posture, tongue resting position, bruxism, biting habits, along with their synonyms and alternative spellings. Connected to OMD with “OR”, AD and possible synonyms were the final part of the search string. Each search strategy was adapted to the used database. 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 the 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 the more recent publications. Articles in English, French, or Dutch were considered for this systematic review, as these were the languages the authors were proficient in. No restrictions were set for the year of publication. After the removal of duplicates, 2652 articles (see Figure 1) were identified and were included in the title and abstract screening.

Protocol

After the 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, consensus between both researchers was required. First title and abstract screening were performed, resulting in 398 remaining articles. After this stage, the full texts of the articles were screened, identifying 36 articles 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. Munn et al.’s [45] working group developed an easy-to-use tool that, among other things, evaluated sample size, recruitment, and reliable data collection and analysis. Two 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 not validated or were completely based on patient or observer report were considered ”high risk”. If not enough information was made available (e.g., not enough information about the intervention), the criterium was rated as ”unclear”. More explanation of the criteria and how to assess them can be found in Munn et al. [45]. Studies were considered to be high risk and excluded for further analysis if the researchers deemed three 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 published, aim, number, age, and gender of the subjects, the assessments performed, and results. These results were grouped according to the disorders considered in the population with malocclusions: AD, biting habits, bruxism, low tongue position, and deviate swallowing. The data are summarized in Tables 2 – 6. 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 1. 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 report and no actual measurement for the diagnosis of OMD. Most of the questionnaires were self-made, non-validated questionnaires. 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 was 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 with malocclusion was the sole emphasis of one article [47]. Another four articles considered the relation of articulation and malocclusion as one of multiple topics [3,48–50]. Of these articles, three articles were part of one big, overarching longitudinal study [3,49,50]. All studies were deemed to have a low risk of bias. These studies are summarized in Table 2.

Botero-Mariaca et al. [47] compared 132 children with AOB to 132 children without AOB 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 were also more common in children with AOB: lingual interposition, lingual thrust, and tongue protrusion. 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 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 articulation disorders. The disordered sounds were primarily alveolar: sigmatisms (i.e., phonetic disorders of the /s/), more specifically sigmatism addentalis (i.e., tongue tip rests on central incisors during the production of /s/) and stridens (i.e., /s/ sound contains a whistling sound). They also showed more disorders of the /n/, as well as more lambdacisms (i.e., phonetic disorders of the /l/), and more disorders of the /t/, specifically addental production of the /t/. However, no significant association was found between the type of malocclusion and the type of articulation disorder [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 2275 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 (1990). 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, see table 4 [37,48,52–54].

Chevitarese et al. [52] considered 112 children between 4 and 6 years old and questioned them about their biting habits. They found a significant association between nail-biting and AOB [52]. Gomes et al. [53] asked the parents of 764 5-year-old children to fill out a questionnaire that asked about biting habits, among other things. Anterior open bite was associated with less nail-biting [53]. The biting habits of 133 5-year-old children were charted using a parent questionnaire by Hebling et al. [54]. No significant difference for nail-biting was found in populations with and without AOB and 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 nailbiting and AOB. Finally, Van Lierde et al. [48], of which the population was described above, asked about biting habits in a questionnaire. They found that the children referred to orthodontists and not referred to orthodontists showed equal nail-biting habits.

Bruxism and Malocclusion

The association between bruxism and malocclusion was discussed separately by five studies and was one of the multiple parameters investigated in two studies, as depicted in Table 4 [48,53,55–59]. All of the studies were deemed to show a low risk of bias, except for the study of Sari and Sonmez [57], 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 [55–57]. Ghafournia and Hajenourozali Tehrani [55] assessed bruxism 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 [60]), and flush terminal plane (i.e, the distal surface of the mandibular deciduous second molar lies in the same vertical plane as the maxillary one [60]) were present more in children with bruxism [55]. Nahás-Scocate et al. [56] determined the presence of bruxism with a questionnaire in 873 children between 2 and 7 years old. Less crossbite was found in the children with bruxism [56]. Sari and Sonmez [57] considered 394 children between 9 and 14 years old and relied on parent interviews to determine the presence of bruxism. In children with mixed dentition, they found the children with bruxism showed more Angle Class I occlusion for first molar teeth, more overjet larger than 6mm, more overbite larger than 5 mm, more scissorbite, and more crossbite for multiple teeth anterior-posterior. In permanent dentition, overjet larger than 6 mm, negative overjet, overbite larger than 5mm, and AOB were significantly more present in children with bruxism [57].

Four studies did not report any association between bruxism and malocclusion [48,53,58,59]. Demir et al. [58] considered 965 children and adolescents between 7 and 19 years. They assessed bruxism with an intra-oral examination and self-report, but they found no significant associations between bruxism and the considered occlusal factors. Gomes et al. [53] also included a question about bruxism in their questionnaire (see above), and found no significant relationship between bruxism and AOB. Gonçalves et al. [59] compared 255 children with bruxism between 4 and 16 years 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 low tongue position and malocclusion. Five selected studies, all with low risk of bias, considered low tongue position as one of the investigated parameters [3,48–50,61], three of which were part of one big longitudinal study [3,49,50].

The population of the longitudinal study [3,49,50] was already discussed above. They examined the children for their resting tongue position [3]. They found significantly more unphysiological tongue posture in children with an overjet larger than 4mm [3]. They also found more unphysiological tongue position, in the 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 low tongue position (about 40% of the crowding and non-crowding groups) [50]. Van Lierde et al. [48] also considered tongue position in their oromyofunctional evaluation. They found significantly impaired tongue function at rest in the orthodontic treatment-seeking population, as well as more anterior tongue position compared to the non-treatment seeking population. On the other hand, Laganà et al. [61] used an evaluation, as well as a questionnaire, to establish the tongue position in 2617 children between 7 and 15 years old. They did not find a significant correlation between 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 6 [3,37,48–50,54,61–63]. The three 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 4mm [3], and the children with AOB [49]. Visceral swallowing was significantly less common in children with crowding [50]. Hebling et al. [54], assessed the swallow of 133 children following the Brazilian oral healthy epidemiological survey.

The children presenting with an atypical swallow showed more AOB and crossbite, compared to children with typical swallows (p=0.01) [54]. Five-hundred-and-three children of a mean age of about 6 years were tested by Kasparaviciene et al. [62]. The investigators examined saliva swallows. They found that children with infantile swallowing had a significantly higher prevalence of AOB (p=0.001). Laganà et al. [61] assessed swallowing as well in their study (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 [63] observed and palpated saliva and water swallows in 243 children examined at 3, 4, and 5 years of age. At 3 years, an equal prevalence of atypical swallowing was found in children with and without crossbite. However, the prevalence of atypical swallowing increased at 5 years 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 (p<0.05) for both the group younger than 6 years and the group between 7 and 12 years. Finally, Van Lierde et al. [48] included swallowing in their oromyofunctional examination. The orthodontic therapy seeking population presented with 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 reported relationships between malocclusions, OMD and AD in children and adolescents between 3 and 18 years. 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, 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 OMDs, AD, and malocclusions, articles that consider a possible link between OMD, AD, and malocclusions were more uncommon. Most of the included articles represented evidence levels 3 and 4 [64]. 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 [3,48,61]. 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, for example, deviate swallowing and pacifier habit, AOB, and crossbite [65]. Moreover, OMD and AD could influence one another as well [66–68]. For example, it was reported that AD improve after orofacial myofunctional therapy, showing that OMD could influence articulation [68,69]. Furthermore, other variables, such as restriction of the nasal passage, have been implicated to cause other OMD, and thus are inherently related [70]. It was, therefore, likely not optimal to consider OMD and AD separately. Especially given that both of these disorders present with high prevalences in children [3,4,18], considering the relationship between OMD and AD to inform optimal treatment is essential. 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 OMDs, (2) OMDs and AD, and (3) OMDs, 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), which all influence the results. Variable terminology and assessments were used for both malocclusion and OMD. Often, different terminology was used to denominate the same concept: for example 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], other studies did provide the used definition [53], 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 for malocclusion was Angle's classification [71], despite the critiques on this particular classification [72,73]. 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 [56], or a different questionnaire and a clinical examination [55]. 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], some only presented significance values for certain aspects of their research [61]. None of the studies reported effect sizes, only the significance level of the results. The described inconsistency in reporting makes it difficult to compare the results of one study with another.

Another common trait across the included studies was the use of questionnaires and parent-reported questionnaires to assess OMD [53,54,59]. 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 the children were the population of interest, questionnaires were often filled out by parents or guardians. Kasparaviciene et al. [62] found a disagreement as high as 28.5% between the parent report and clinical observation. Therefore, to be truly valid, questionnaires should be combined with clinical examinations, rather than solely relying on questionnaires, as is now often the case.

Finally, all but three articles included in the 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 multi-disciplinary approach, there still was an emphasis on malocclusion. Another possible explanation could be that, while oromyofunctional therapy had existed for several years, its effectiveness was questioned until the American Speech-Language-Hearing Association revised its position in 1990 [74].

The 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. [61]. On the other hand, Gonçalves et al. [59] 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 [75–77] but were described in only one article included in this review [56]. Similarly, a history of speech-language therapy was only mentioned in two studies [47,56], 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 and confounding variables were considered.

Lastly, three studies focused on only one malocclusion in particular: AOB [37,47,53]. The AOB might receive more attention compared to other malocclusions because of its difficult treatment [37,47]. Frequently, the correction of an AOB has 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, for example not mentioning how the sounds were elicited or if words or sentences were pronounced, or 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 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]. The AOB could change the articulatory surface and often co-occurs with skeletal abnormalities leading to “long-face syndrome” [78]. The exact nature of the co-occurrence of malocclusions and AD (causal vs. compensatory) remains to be seen.

On biting habits, on the other hand, this review could not provide conclusive findings, though none of the studies focussed solely on biting habits. While one study found a significant relationship between nail-biting and AOB [52], Gomes et al. [53] 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 [37,48,54]. A possible explanation for these inconclusive results could be that biting habits are more diverse and more transient than for example non-nutritive sucking habits, upon which the literature has extensively focused. It was established that mainly constant forces, not transient ones, cause teeth to move [12,13]. Furthermore, the presence of biting habits was only in one case verified with a clinical examination; the other studies relied on self-report. Biting habits could be considered body-focussed repetitive behavior, as could sucking habits [8]. Some studies also associated the presence of biting habits with that of sucking habits [7,79]. 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, 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: flush terminal plane and mesial step [55], less crossbite [56], differences in overjet, overbite, open bite, and crossbite [57]. The other four 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. [80] 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 [80–82].

There appeared to be some connections between low physiological tongue position and malocclusal factors [48]. Relationships of low tongue position with deviating overjet, AOB, and crossbite were suggested [3,49]. However, one study found no connection at all [61]. The tongue has often been implicated in the occurrence of malocclusions [83]. Low tongue postures have been connected to multiple malocclusions, such as Class III malocclusion [84], crossbite [85], and AOB [86]. 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 co-occurrence of deviate swallowing and AOB, with often more than half of the children with deviate swallow presenting with AOB [37,49,54,61,62]. This appeared to be the most prevalent connection between an OMD and malocclusion found in this review. This is supported by the literature, that already described this connection previously [6]. However, according to some theories, deviant swallowing would exert high 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 OMDs such as sucking behavior or low resting tongue postures [63]. 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 [54,63]. However, less evidence supported this association.

To summarize, there were only a few high-quality articles that link 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 [64] on the relationship between malocclusion and both OMD and AD. Literature would benefit from high-quality studies focused on specific OMD, AD, and/or malocclusion, controlling for the non-studied OMD. Broader studies that look 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 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 to study 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 non-physiological swallowing may often co-occur with an anterior open bite. 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 low tongue position in rest, there was not enough concurring evidence to support a similar connection. More high-quality, longitudinal research is needed to further elucidate OMD and AD along with malocclusions.

Statements

Statement of Ethics

An ethics statement was not required for this study type, no human or animal subjects were used.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

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

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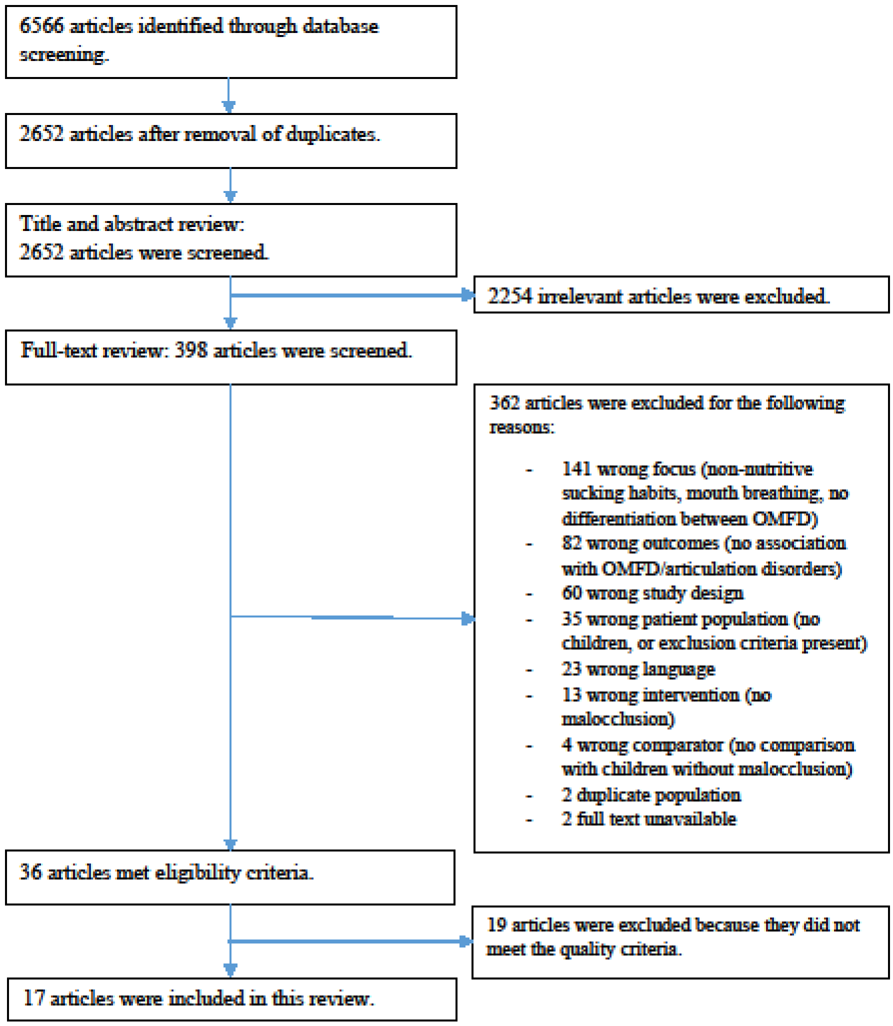
Figures

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



Tables

Table 1

Overview of the quality assessment of the included articles.

	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. (2018)	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	Low	Low	Low
Chevitarese et al. (2002)	Low	Low	Low	Unclear	High	Low	High	Low	Low	Low	Unclear	Low	Low
Demir et al. (2004)	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Unclear	Low	Low
Ghafournia and Hajenourozali Tehrani (2012)	Low	Low	Low	Unclear	Low	Unclear	Low	Low	Low	Low	High	Low	Low
Gomes et al. (2018)	Low	Low	Low	Low	Low	Low	Unclear	Low	Low	Low	Unclear	Low	Low
Gonçalves et al. (2010)	Low	Low	Low	Unclear	Low	Low	Low	Low	Low	Low	High	Low	Low

Grabowski et al. (2007) **Stahl et al. (2007)** **Seemann et al. (2011)**	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Unclear	Low	Low
Hebling et al. (2008)	Low	Low	Low	Low	Low	Low	Unclear	Low	Low	Low	Unclear	Low	Low
Kasparaviciene et al. (2014)	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	High	Low	Low
Lagana et al. (2013)	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	Unclear	Low	Low
Nahás-Scocate et al. (2014)	Low	Low	Low	Unclear	Low	Low	High	Low	Low	Low	Low	Low	Low
Ovsenik (2009)	Low	Low	Low	Unclear	Low	Low	High	Low	Low	Low	Unclear	Low	Low
Sari and Sonmez (2001)	Low	Low	Low	Unclear	Low	Low	High	Unclear	Low	Low	Unclear	Low	Unclear
Urzal et al. (2013)	Low	Low	Low	Unclear	Low	Low	High	Unclear	Low	Low	Unclear	Low	Low
Van Lierde et al. (2015)	Low	Unclear	Low	Unclear	Low	Unclear	Low	Low	Low	Low	High	Low	Low

Table 2

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

Authors	Population	Articulation assessment	Orthodontic assessment	Results
Botero-Mariaca et al. (2018)[a]	264 Colombian children: - 8-16y - *M*= 11.62y, SD= 2.5 - 56.1%♀, 43.9%♂ 132 children with AOB 132 children with normal occlusion	- Unclear who performed 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% 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 the contact of the tongue with the palatal rugae were protective.
Grabowski et al. (2007) Seemann et al. (2011) Stahl et al. (2007)	3041 German speaking children: - 1496♀, 1545♂ 766 primary dentition - *M*=4.5y, *SD*= 0.9y 2275 early mixed dentition - *M*=8.3y, *SD*= 1.4y	- By two dentists and two orthodontists - Elicitation of 8 words - Assessment of /l/, /n/, /d/, /t/, /s/ as physiological (/l/, /n/, /d/, /t/, /s/), interdental (/l/, /n/, /d/, /t/, /s/), addental (/s/) or lateral (/s/)	- By two dentists and two orthodontists - Sagittal occlusal relationship in the anterior and posterior region - Transverse occlusal relationship in posterior region	Articulation disorders in 52.1% in AOB vs. 28% in normal occlusion (p≤0.001) Articulation disorders in 51.0% in crossbite vs. 28% in normal occlusion (p≤0.001) Articulation disorders in 16% in crowding vs. 21% in non-crowding (p=0.05)

			- Vertical occlusal relationship in anterior region	
Van Lierde et al. (2015)	110 Flemish-speaking children: 56 children referred to an orthodontist - 32♀, 24♂ - 7-12y, *M*=10.2 54 children not referred to an orthodontist - 29♀, 25♂ - 6-12y, *M*=9.3y	- By two SLPs in consensus - Picture naming test (word level) - Phonetic inventory Phonetic analysis Speech intelligibility	- By two orthodontists - Occlusion (Angle) Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Phonetic disorders per child in 2.3 sounds in orthodontic group vs. 1.92 in non-orthodontic group (*p*<0.001). Sigmatism in 59% in orthodontic group vs. 22% in non-orthodontic group (p<0.001) Phonetic disorder of /n/: 44% in orthodontic group vs. 24% in non-orthodontic group (p=0.028) Lambdacism in 43% in orthodontic group vs. 19% in non-orthodontic group (p=0.001) Disorders of /t/ in 41% in orthodontic group vs. 13% in non-orthodontic group (p=0.001)

Note. AOB = anterior open bite, M = mean, p = significance level, SD = standard deviation, SLP = speech-language pathologist, y = year, ♀ = female, ♂ = male.

[a] The studies in bold were the studies that looked at the association between articulation and malocclusion exclusively.

Table 3

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

Authors	Population	Biting habit assessment	Orthodontic assessment	Results
Chevitarese et al. (2002)	112 Brazilian children - 60♀, 52♂ - 4-6y, *M*= 61m, *SD*= 6.67m	- 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. (2018)	764 Brazilian children - 363♀, 401♂ - 5 y	- Parent questionnaire (pre-tested, non-validated)	- By calibrated dentists - Oral examinations - AOB	AOB in 9.7% of nail biting group, 17.6% of non-nail biting group (*p*=0.007)
Hebling et al. (2008)	133 Brazilian children - 68♀, 65♂ - 5 y	- Parent questionnaire (pre-tested, non-validated)	- By calibrated examiners - Dental Aesthetic Index Open bite Crossbite	AOB in 21% of nail biting group vs. 33% in non-nail biting group (non-significant) Crossbite in 13% of the nail biting group vs. 17% of non-nail biting group (non-significant)
Urzal et al. (2013)	568 Portuguese children: 189 primary dentition - 88♀, 101♂ - M= 5.39y, *SD*= 0.94y 379 mixed dentition - 195♀, 184♂ - M= 8.23y, *SD*= 0.99y	- 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. (2015)	110 Flemish-speaking children:	- Questionnaire (not pre-tested or validated)	- By two orthodontists - Angle classification	Nail-biting habit in 32% of the orthodontic group vs. 31% of non-orthodontic group (non-significant)

	56 children referred to an orthodontist - 32♀, 24♂ - 7-12y, *M*=10.2) 54 children not referred to an orthodontist - 29♀, 25♂ - 6-12y, *M*=9.3y		Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	

Note. AOB = anterior open bite, M = mean, m = months, p = significance level, SD = standard deviation, SLP = speech-language pathologist, y = year, ♀ = female, ♂ = male.

Table 4

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

Authors	Population	Bruxism assessment	Orthodontic assessment	Results
Demir et al. (2004)[a]	965 Turkish children 493♀ - *M*= 12.7y, *SD*= 3.9y 472♂ - *M*= 12.9y, *SD*= 4.1y	- Self-report - Intra-oral 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 (2012)[a]	400 Iranian children 51 children with bruxism - 45.01%♀, 54,9%♂ - 3-6y 349 children without bruxism	- Parent questionnaire (not pre-tested or validated) - Intraoral examination	- By one 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 plan in 38% of the children with flush terminal plane group (*p*=0.023)
Gomes et al. (2018)	764 Brazilian children - 363♀, 401♂ - 5 y	- Parent questionnaire (pre-tested, non-validated)	- By calibrated dentists - Oral examinations - AOB	AOB in 13% of children with bruxism vs. 15% of the children without bruxism (non-significant).
Gonçalves et al. (2010)[a]	592 Brazilian children - 4-16y 255 children with bruxism - 128♀, 127♂ 337 control	- Questionnaire (not pre-tested or validated)	- By one examiner - Normal occlusion Crowding Crossbite Anterior open bite Anterior deep bite	There was no relationship between the occlusal factors and bruxism.

	- 184♀, 153♂		Overjet Angle classification	
Nahás-Scocate et al. (2014)[a]	873 Brazilian children - 434♀, 439♂ - 2y1m – 6y11m	Questionnaire (cfr. Junqueira et al., 2013)	- By three calibrated examiners - Posterior crossbite	Bruxism in in 17% of children with crossbite vs. 30% of children without crossbite (p=0.002).
Sari and Sonmez (2001)[a]	394 Turkish children: - 9-14y 182 mixed dentition - 80♀, 102♂ 212 permanent dentition - 114♀, 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 bruxism group vs. 65% of non-bruxism group (p<0.05) Overjet >6mm in 8% of bruxism group vs. 0% of non-bruxism group (p<0.01) Overbite >5mm in 8% of bruxism group vs. 0 % of non-bruxism group (p<.01) Scissorbite in 17% of bruxism group vs. 9% of non-bruxism group (p<0.05) Crossbite in 4% of bruxism group vs. 0% of the non bruxism group (p<0.01). In permanent dentition: Overjet >6mm in 6% of the bruxism group vs. 1% of non-bruxism group (p<0.05) Negative overjet in 6% of the bruxism group vs. 1% of non-bruxism group (p<0.05) Overbite>5mm in 9% of the bruxism group vs. 1 % of non-bruxism group (p<0.01) AOB in 13% of the bruxism group vs. 0.5% of non-bruxism group (p<0.01)
Van Lierde et al. (2015)	110 Flemish-speaking children: 56 children referred to an orthodontist - 32♀, 24♂ - 7-12y, M=10.2 54 children not referred to an orthodontist	- By two SLPs in consensus - Oromyofunctional examination - Questionnaire (not pre-tested or validated)	- By two orthodontists - Angle classification Mandibular displacement Buccal crossbite Anterior open bite Overjet	Bruxism in 34% of the orthodontic group vs. 18% of the non-orthodontic group (non-significant).

	- 29♀, 25♂ - 6-12y, *M*=9.3y		Overbite	

Note. AOB = anterior open bite, M = mean, m = months, p = significance level, SD = standard deviation, SLP = speech-language pathologist, WHO = World Health Organization, y = year, ♀ = female, ♂ = male.

[a] The studies in bold were the studies that looked at the association between articulation and malocclusion exclusively.

Table 5

Overview of the articles discussing the association between non-physiological tongue position and malocclusion.

Authors	Population	Low tongue position assessment	Orthodontic assessment	Results
Grabowski et al. (2007) Seemann et al. (2011) Stahl et al. (2007)	3041 German-speaking children: - 1496♀, 1545♂ 766 primary dentition - *M*=4.5y, *SD*= 0.9y 2275 early mixed dentition - *M*=8.3y, *SD*= 1.4y	- By two dentists and two orthodontists - Normal tongue posture - Pathological tongue posture: interdental or caudal tongue position	- By two 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>4mm vs. ±25% of overjet=0-2mm (*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) Uphysiological tongue posture in 46% of reduced overjet (*p*<0.001)
Lagana et al. (2013)	2617 Albanian children - 1360♀, 1257♂ - 7-15y	- By five trained examiners - Orthodontic evaluation - Anamnestic questionnaire (not pre-tested or validated)	- By five trained examiners - Orthodontic examination (WHO guidelines)	Low tongue position did not show a significant correlation with any malocclusion characteristic.
Van Lierde et al. (2015)	110 Flemish-speaking children: 56 children referred to an orthodontist - 32♀, 24♂ - 7-12y, *M*=10.2 54 children not referred to an orthodontist - 29♀, 25♂ - 6-12y, *M*=9.3y	- By two SLPs in consensus - Oromyofunctional examination (cfr. Lembrechts et al., 1999) - Questionnaire (not pre-tested or validated)	- By two 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 non-orthodontic group (*p*<0.001) Decreased tongue function in 18% of the orthodontic group vs. 15% of non-orthodontic group (*p*<0.001) Anterior tongue position in 66% of the orthodontic group vs. 22% of non-orthodontic group (*p*<0.001).

Note. AOB = anterior open bite, M = mean, p = significance level, SD = standard deviation, SLP = speech-language pathologist, y = year, ♀ = female, ♂ = male.

Table 6

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

Authors	Population	Swallowing assessment	Orthodontic assessment	Results
Grabowski et al. (2007) Seemann et al. (2011) Stahl et al. (2007)	3041 German-speaking children: - 1496♀, 1545♂ 766 primary dentition - *M*=4.5y, *SD*= 0.9y 2275 early mixed dentition - *M*=8.3y, *SD*= 1.4y	- By two dentists and two orthodontists - Water and saliva swallow (Garliner) - Physiological swallowing - Anterior interdental swallowing - Bilateral interdental swallowing - Total interdental swallowing	- By two 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	Visceral swallow in ±76% of overjet>4mm vs. ±48% of overjet 0-2mm (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. (2008)	133 Brazilian children - 68♀, 65♂ - 5 y	- 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. (2014)	503 Lithuanian children - 243♀, 260♂ - *M*=5.95y, *SD*= 0.61y	- By one investigator - Saliva swallows	- By one investigator - Incisal segments (vertical overlap, AOB) - Lateral segments (Angle's classification) - Transverse relation (normal, buccal	Children with infantile swallowing had a significantly higher prevalence of AOB (p=0.001).

			crossbite, lingual crossbite) - Spacing	
Lagana et al. (2013)	2617 Albanian children - 1360♀, 1257♂ - 7-15y	- By five trained examiners	- By five 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 (2009)	243 Slovenian children - 124♀, 119♂ - Examined at 3, 4, 5 years	- Unclear who performed the assessment - Saliva swallow or small amounts of water - Observation + palpation	- Unclear who performed the assessment - Posterior crossbite - Midline deviation - Transverse buccal relationships	Atypical swallowing in ±55% of children with and without crossbite (non-significant) The prevalence of deviate swallowing was not significantly different in children with and without crossbite. The prevalence of deviate swallowing increased over time for children with crossbite (to ±62%) , while it decreased for children without crossbite (±35%).
Urzal et al. (2013)	568 Portuguese children: 189 primary dentition - 88♀, 101♂ - *M*= 5.39y, *SD*= 0.94y 379 mixed dentition - 195♀, 184♂ - *M*= 8.23y, *SD*= 0.99y	- By students (following training) - Clinical examination	- By students (following training) - AOB	In both the 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. (2015)	110 Flemish-speaking children: 56 children referred to an orthodontist - 32♀, 24♂ - 7-12y, *M*=10.2 54 children not referred to an orthodontist - 29♀, 25♂ - 6-12y, *M*=9.3y	- Oromyofunctional examination (cfr. Lembrechts et al., 1999) o Swallowing: anterior interdental/addental tongue thrust, uni- or bilateral tongue thrust - Questionnaire (not pre-tested or validated)	- By two orthodontists - Angle classification Mandibular displacement Buccal crossbite Anterior open bite Overjet Overbite	Impaired lip position during swallowing in 5% of orthodontic group vs. 0% of non-orthodontic group ($p=0.006$) Tongue thrust swallow in 50% of orthodontic group vs. 22% of the non-orthodontic group ($p=0.03$) Tongue thrust swallowing and deep bite were associated ($p=0.041$).

Note. AOB = anterior open bite, M = mean, p = significance level, SD = standard deviation, SLP = speech-language pathologist, y = year, ♀ = female, ♂ = male.