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SYSTEMATIC REVIEW

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Effects of non-nutritive sucking habits on malocclusions: a systematic review

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Abstract

The development of the craniomandibular system is guided by genetic interactions and environmental factors, including specific habits such as breastfeeding, bottle feeding, thumb sucking and the use of pacifiers. These habits can have a considerable impact on the growth of the developing jaws and can lead to malocclusion in children. This review aims to investigate potential associations between non-nutritive sucking habits (NNSHs) and malocclusions compared to the presence of nutritive sucking habits (NSHs). To carry out this systematic review, we followed the PRISMA protocol and performed a bibliographic search of the existing literature until April 2023 in the following electronic databases: Medline, PubMed, The Cochrane Library and Embase. Out of a total of 153 records, we included 21 studies. We found that the chances of diagnosing a malocclusion were higher for children with bottle nutrition when compared to breast-fed children. Breastfeeding provides protection against malocclusions. In the same manner, persistent NNSH habits appeared to be associated with increased chances of having malocclusions. The longer the child was breastfed, the shorter the duration of the pacifier habit and the lower the risk of developing moderate/severe malocclusions. The duration of the habits has a positive influence on the appearance of occlusion defects.

Keywords

Thumb sucking; Pacifier; Breastfeeding; Bottle feeding; Malocclusion; Orthodontics; Sucking habits

1. Introduction

Oral habits are defined as repetitive behaviors that could result in defects in the structure of teeth [1]. In the literature, sucking habits are described in two ways: nutritive (breastfeeding and bottle feeding) and non-nutritive sucking. NNSH is defined by the solicitation of muscle activity, but without fulfilling a feeding purpose, for example, thumb or pacifier sucking. The effect of NNSH depends on the nature, onset and duration of the habit. Sucking behaviors are physiological habits in newborns that stimulate the orofacial muscles and contribute to normal growth; however, the persistence of non-nutritive sucking habits can lead to long-term problems and create defects in the stomatognathic system [2–8].

The main malocclusions associated with sucking habits are frequently skeletal class II and III, open bite (OB), deep bite (DB) and crossbite (CB) [1, 9, 10]. The prevalence of malocclusions in different age groups ranges from 20% to 93%. A combination of hereditary and environmental factors acts together to produce malocclusions [11, 12]. To correct malocclusions, the association between speech therapists, pediatricians, otolaryngologists and orthodontists is an important issue in the treatment of patients with oro-dysfunction, as the quality of interdisciplinary patient care is very relevant for the success of the treatment and for the long-term stability of the treatment outcome [13–15].

A systematic review published in 2016 [16] highlighted the risks of non-nutritive habits om malocclusion, such as sucking on a finger or using a pacifier. This study emphasized the need to educate parents about these behaviors in children. It is therefore important to update our research to follow up this prevention dynamic. Knowledge of the etiology of malocclusions is very important for the orthodontist, both to treat the patient with appropriate remedies, and to advise the parents well and provide the appropriate interventions to avoid malocclusions of all kinds.

The main objective of this review was to summarize, in a systematic manner, the existing literature to explore the relationship between non-nutritive sucking habits (NNSHs) and the occurrence of malocclusion, as well as the impact of nutritive sucking habits (NSHs) on development. Our study aims to provide a deeper understanding of how different sucking habits can influence the development of malocclusion.

2. Material and methods

2.1 Eligibility criteria

When selecting published articles, we applied inclusion criteria according to the PECO method, as described below.

- Population: Children in good health, from birth to 6 years-of-age, who had a primary or mixed dentition.

- Exposure: Studies focusing on the presence of NNSHs, such as pacifier use or finger sucking and the impact of NSHs, such as breastfeeding and bottle-feeding.

- Comparison: Comparisons of the prevalence of NNSHs, including pacifier use or finger sucking, with the occurrence of malocclusion. Studies involving the potential impact of NSHs, such as breastfeeding and bottle-feeding, on the development of malocclusion.

- Outcome: Studies focusing on the frequency, intensity, duration and time of cessation of each habit and its relationship with the development of malocclusions in the three planes of space (sagittal, vertical, transversal) was evaluated.

- Studies: Observational cross-sectional studies, randomized and non-randomized cohorts, were included without language or publication time restrictions.

Articles were excluded if they involved children with systemic diseases, craniofacial syndromes or anomalies; we also excluded systematic reviews and meta-analyses.

2.2 Information sources

To conduct this systematic review, we followed the PRISMA protocol: Preferred Reporting Items Protocol for Collecting Systematic Reviews and Meta-Analyses [17, 18].

2.3 Search strategy

A literature search was performed in the following bibliographic databases: PubMed (Medline), The Cochrane Library (CDSR, CENTRAL and DARE), Embase and Scopus until April 2023. Grey literature was also searched.

The search strategy used the following keywords: (malocclusion* OR malocclusion (Mesh)) AND (Breastfed* OR Breastfeeding (Mesh)) AND (Habit* (Mesh) OR Finger sucking (Mesh)) AND (Pacifier (Mesh) OR Orthodon* (Mesh) OR Myofunctional therapy (Mesh)). The search strategy can be found in Table 1: Search strategy.

2.4 Data collection process

Once the bibliographic search had been performed, the selection of studies was carried out in two phases. In the first phase, two of the authors (CS and LA) evaluated the titles and abstracts of the articles independently and selected those that met the inclusion criteria. In the second phase, full texts and articles that did not contain sufficient information in the title or abstract were reviewed to decide whether they should be included. In case of disagreement (in both phases), a third author (LT) was consulted to reach consensus.

2.5 Data items

The type of study, the sample size, the method used to acquire information on the patients and the comparison between the different types of habits and malocclusions resulting from each study are described in Table 2.

2.6 Risk of bias assessment: quality of evidence

To assess the methodological quality/risk of bias of the selected articles, CS and LA independently used the checklist for cross-sectional studies and the checklist for cohort trials of the JBI Systematic Review [19, 20]. The checklist for cross-sectional studies consisted of eight questions while that for cohort studies consisted of 11 questions. Each question was answered with a “yes” or “no”. To evaluate the different studies, we allocated a score of 1 for the answer: “yes” and 0 for “no” and added the scores for comparison. For cross-sectional studies, a total of less than 4 points was considered as high risk, 4 points as moderate bias, and more than 4 points as low risk. For cohort studies, a total of less than 6 points was considered as high risk, 6 points as moderate bias, and more than 6 points as low risk.

2.7 Risk of bias across studies

We used the GRADES system [21] to assess the overall quality of the included articles. This method includes factors that rate the score as risk of bias, imprecision, inconsistency, indirectness and publication bias and other factors that increase the level as a magnitude of effect, dose-response gradient while taking all confounding factors into account.

2.8 Effect measures

The main outcomes assessed were the relationship between nutritive and non-nutritive sucking habits and the development of malocclusions, the influence of NNSHs and other variables, such as the socioeconomic status of the children and the presence of oral respiration, on the apparition of sucking habits. These outcomes were presented in Table 3.

3. Results

Initially, 153 records were identified following application of the literature search strategy. After eliminating duplicates, 116 records were retrieved. Eighty-six records were discarded after the examination of titles and abstracts. In the second phase, by evaluating the full texts, eight articles were eliminated: five articles were excluded because they discussed only one aspect of the study (only the pacifier effect and did not discuss breastfeeding or malocclusions). Another article was a poster and did not feature specific information about the study. Two other studies were discarded because the population did not meet the inclusion criteria (preterm infants, adolescents). Therefore, 21 studies were included in the systematic review, all of them published in English, as illustrated in Fig. 1.

TABLE 1. Search strategy.

MedLine (PubMed) (N = 270,679)	Database: MESH All <2000 to 2023>	
	Search Strategy:	
	1. Malocclusion	51,302
	2. Breastfeed*	90,565
	3. Habit*	20,106
	4. Fingersucking	1370
	5. Pacifier	3697
	6. Orthodon*	103,316
	7. Myofunctional Therapy	323
	8. 3 OR 4	284,892
	9. 5 OR 6 OR 7	108,814
	10. 1 AND 2 AND 8 AND 9	121
Cochrane (N = 19,805)	Database: MESH All <2000 to 2023>	
	Search Strategy:	
	1. Malocclusion	1466
	2. Breastfeed*	5709
	3. Habit*	271
	4. Fingersucking	8
	5. Pacifier	59
	6. Orthodon*	2608
	7. Myofunctional Therapy	41
	8. 3 OR 4	8969
	9. 5 OR 6 OR 7	4365
	10. 1 AND 2 AND 8 AND 9	0
EMBASE (N = 1,063,969)	Database: MESH All <2000 to 2023>	
	Search Strategy:	
	1. Malocclusion	26,807
	2. Breastfeed*	46,813
	3. Habit*	443,092
	4. Fingersucking	66
	5. Pacifier	4220
	6. Orthodon*	47,473
	7. Myofunctional Therapy	731
	8. 3 OR 4	443,103
	9. 5 OR 6 OR 7	51,681
	10. 1 AND 2 AND 8 AND 9	27
Scopus (N = 170,637)	Database: MESH All <2000 to 2023>	
	Search Strategy:	
	1. Malocclusion	6580
	2. Breastfeed*	7946
	3. Habit*	119,001
	4. Fingersucking	56
	5. Pacifier	567
	6. Orthodon*	1,006,573
	7. Myofunctional Therapy	348
	8. 3 OR 4	12,545
	9. 5 OR 6 OR 7	13,456
	10. 1 AND 2 AND 8 AND 9	5
		153

**: Truncation is a technique that broadens your search to include various word endings. To use truncation, enter the root of the word with the truncation symbol at the end. E.g., Breastfeed* finds breastfeed, breastfeeds or breastfeeding.*

TABLE 2. Description of the included articles.

	Authors	Methods	Numbers of participants	Age (yr)	Comparison		
					Types of Habits	Types of Malocclusions	Other Variables
1	Sum *et al.* [22]	Questionnaire and clinical examination	851 (469 M–378 W–4 unreported gender)	2–5	Presence and Duration NSH and NNSH	Sagittal, Vertical, Transverse Malocclusion	Social and Economic Variables
2	Bueno *et al.* [23]	Questionnaire and clinical examination	138	4–5	Duration BF and NNSH	Sagittal, Vertical, Transverse Malocclusion, Lack of Maxillary Space	Nasal Airway Sizes
3	Romero *et al.* [24]	Questionnaire and clinical examination	1377 (50.1% M–49.9% W)	3–6	Duration NSH and presence NNSH	OB	Social and Economic Variables
4	Chen *et al.* [25]	Questionnaire and clinical examination	743 (398 M–336 W)	3–6	Frequency and Duration NSH y NNSH	Sagittal, Vertical, Transverse Malocclusion, Crowding, Diastemas	Social Level and Education Parents
5	Agarwal *et al.* [26]	Questionnaire and clinical examination	180 (54.9% M y el 45.1% W)	4–6	Duration NNSH Y NSH	OB, Crossbite, ICD, IMD	/
6	Kobayashi *et al.* [27]	Questionnaire and clinical examination	1377 (690 M–687 W)	3–6	Frequency and Duration NSH y NNSH	Crossbite	/
7	Melink *et al.* [28]	Questionnaire, clinical examination and otolaryngological analysis	60	5–6	Duration BF and NNSH	Transverse Malocclusion, Crossbite, Relationship Canine Temporal and Midline	Tympanic Membrane, Nasal Mucosa and Nasal Deviation, Size of Adenoids and Types of Respiration
8	Diouf *et al.* [29]	Questionnaire and plaster model examination	226 (123 M Y 10 W)	5–6	BF and NNSH history	ICD Y IMD Maxilla, Maxillary Anterior Length, Palate Depth, Overjet, Overbite, Transverse Discrepancy	/
9	Moimaz *et al.* [30]	Examination at 12, 18 and 30 mon and clinical examination at 30 mon	80	12 mon–2.5 yr	Duration NNSH Y NSH	Overjet, Overbite, Crossbite	Nasal/Mouth breathing at night
10	López Del Valle *et al.* [31]	Questionnaire and clinical examination	540: (52% W/48% M)	6 mon–6 yr	BF and NNSH history	OB, Crossbite, Crowding, Molar/Canine Relationship	/
11	Ling *et al.* [32]	Questionnaire and clinical examination	851	2–5	Frequency and Duration NSH y NNSH	Sagittal, Vertical, Transverse Malocclusion	/

TABLE 2. Continued.

	Authors	Methods	Numbers of participants	Age (yr)	Comparison		
					Types of Habits	Types of Malocclusions	Other Variables
12	Traebert *et al.* [33]	Questionnaire and clinical examination	655	6	Types of lactation and NNSH	OB, Crossbite, Overjet, Overbite >4 mm, Class II y III Molar/Canine	Social level parents and oral breathing
13	Lopes-Freire *et al.* [34]	Questionnaire and clinical examination	275: (144 (52.4%) M/131 (47.6%) W)	3–6	Presence and Duration NSH and NNSH	Sagittal, Vertical, Transverse Malocclusion	/
14	Da Costa *et al.* [35]	Questionnaire and clinical examination	489	2–5	Types of lactation and NNSH	Sagittal, Vertical, Transverse Malocclusion	Social level parents
15	Warren *et al.* [36]	Examination at 0, 3, 6, 9, 12, 16, 20 and 24 mon of the habits and examination of the plaster models	372	4, 5–5	Frequency NSH and NNSH	Sagittal, Vertical, Transverse Malocclusion, ICD y IMD Maxilla, Palate Depth	/
16	Jabbar *et al.* [37]	Questionnaire and clinical examination	911: (461 M/450 W)	3–6	BF and NNSH history	Overjet–Crossbite–Class Canine	Demographic and Socioeconomic Level, N° children at home, Economic Level
17	Charchut *et al.* [38]	Questionnaire and clinical examination	121	2–6	Frequency and Duration NSH y NNSH	Sagittal, Vertical, Transverse Malocclusion	Race
18	Caramez da Silva *et al.* [39]	Questionnaire at 7, 30, 60, 120 and 180 days and clinical examination 3–5 yr old	153	3–5	Duration NSH y NNSH	Sagittal Malocclusion	Sociodemographic variables
19	Peres *et al.* [40]	Questionnaire at 0, 3, 6 and 12 months and clinical examination	1123: (588 M/535 W)	0–5	Duration NSH y NNSH	OB, Crossbite	Socioeconomic and Demographic, Gestation, Access to health services, Sex of the child, Birth Weight, Head Perimeter and Schooling
20	Peres *et al.* [41]	Questionnaire at 0, 3, 12, 24, 48 mon and clinical examination 5 yr	359: (193 (53.8%) M/166 (46.2%) W)	0–4	Frequency and Duration NSH y NNSH	Overjet, OB, Crossbite	Demographic, Social Level, Respiratory Disease
21	Vasconcelos *et al.* [42]	Questionnaire and clinical examination	1308: (53% M/41% W)	2–5	BF and NNSH history	OB, Overjet, Crossbite, Lack of maxillary space	Social Level Parents

yr: year's old; NSH: Nutritive sucking habit; NNSH: Non-nutritive sucking habits; BF: Breastfeeding; OB: Open bite; ICD: Intercanine distance; IMD: Intermolar distance; M: Men; W: Women.

TABLE 3. Analysis of the results.

	Authors	Results		
		Influence of NSH on Malocclusions	Influence of NNSH on Malocclusions	Influence of NSH on NNSH
1	Sum *et al.* [22]	BF: < probability of developing an increased Overbite and Overjet. Longest duration of BF: Highest probability of class I. BF duration was not associated with crossbite in the primary dentition.	/	/
2	Bueno *et al.* [23]	BF increased the possibility of having normal overbite.	Longer pacifier duration: Higher risk of developing OB and crossbite, and increasing overjet, and overbite. More than 3 years, more probability of having maxillary deficiency.	/
3	Romero *et al.* [24]	BF duration (>12 mon): Inverse relationships with the prevalence of OB even in children without NNSH. Exclusive BF: Stimulating correct oral development and dental occlusion.	NNSH persistent: increased OB chances.	BF duration (>12 mon): Inverse relationships with the prevalence of NNSH. Exclusive BF: effects of preventing the acquisition of NNSH.
4	Chen *et al.* [25]	BF <6 mon (without NNSH): Negatively affected the maxillary arch growth, conducing to a crossbite development. Feeding bottle >18 mon: Non-mesial terminal plane and class II canine relationship.	Pacifiers produced an excessive horizontal overbite and an absence of mandibular space. Thumb induced OB, Crossbite, an absence of maxillary space but had no influence on class II.	BF <6 mon (without NNSH): increased the probability to use a pacifier (No thumb).
5	Agarwal *et al.* [26]	BF <6mon: Increased prevalence of NNSH and crossbite in comparison with BF ≥6 mon. Maxillary ICD, Maxillary and Mandibular IMD: Increased with BF >6 meses.	There was not a statistically significant association between the NNSH and the prevalence of OB and crossbite.	/
6	Kobayashi *et al.* [27]	A short duration of exclusive BF without NNSH produced an increased crossbite.	/	/
7	Melink *et al.* [28]	The type of feeding had not influence on the presence of crossbite and ICD-IMD.	A longer duration of pacifier produced an increase in crossbite and a decrease in IMD.	A long time of BF was associated with a short duration of the pacifier (inverse proportion).

TABLE 3. Continued.

	Authors	Results		
		Influence of NSH on Malocclusions	Influence of NNSH on Malocclusions	Influence of NSH on NNSH
8	Diouf *et al.* [29]	Maxillary anterior length and depth increased in mixed BF. No other significant differences have been discovered. BF was associated with an increased overjet and OB.	With NNSH: Anterior maxillary arch length increased. With thumb habit: Overbite decreased.	
9	Moimaz *et al.* [30]	A combination of bottle feeding (12 and 30 mon) and oral breathing was associated with crossbite.	NNSH produced a higher prevalence of OB, increased overjet and overbite.	/
10	López Del Valle *et al.* [31]	Long time BF and short time bottle feeding: occlusion standard	/	/
11	Ling *et al.* [32]	/	Pacifier: increased the probability of having finger sucking habits. Finger sucking habits produced sagittal Malocclusions: Class II and overjet >3.5 mm. The combination of Pacifier and Thumb induced vertical malocclusions (increased OB and decreased overbite) but was not associated with transverse malocclusions (crossbite or changes in the intercanina/intermolar widths).	Exclusive BF >6 mon: Decreased the use of a pacifier daily
12	Traebert *et al.* [33]	/	There was no association between Molar/canine relationship class II or III, OB, Pacifier use and Oral Breathing.	/
13	Lopes-Freire *et al.* [34]	No significant association was found between NSH (exclusive BF or bottle feeding) and malocclusions.	No significant association between the intensity and duration of NNSH.	BF had a protective effect: Decreased use of pacifier (not thumb)
14	Da Costa *et al.* [35]	/	Pacifier worsened the occlusal conditions.	/

TABLE 3. Continued.

	Authors	Results		
		Influence of NSH on Malocclusions	Influence of NNSH on Malocclusions	Influence of NSH on NNSH
15	Warren *et al.* [36]	There was no relationship between duration of BF during the first year of life and any dental arch or occlusal parameters.	NNSH: significantly higher risk of crossbite and OB, and increased overbite. Thumb sucking caused greater upper ICD depths and molar arch, increased overjet and overbite but had no influence on crossbite. The longer the duration of thumb sucking, the greater was the overjet and the higher was the prevalence of OB.	/
16	Jabbar *et al.* [37]	Bottle feeding produced an increased overjet and a Class II primary canine relationship.	NNSH produced an increased overjet and a Class II primary canine relationship.	/
17	Charchut *et al.* [38]	Bottle feeding (12 and 18 mon) increased the chances of having OB.	Pacifier increased the probability of OB. Finger sucking increased probabilities of anomalous protrusion but there were not statistically significant associations between finger sucking, distal occlusion,Overbite and OB.	Bottle feeding (0 and 6 mon) increased the chances of pacifier use.
18	Caramez da Silva *et al.* [39]	BF $\geq$12 mon: Protection factor against distoclusion.	Distoclusion was associated with NNSH but not with finger sucking.	/
19	Peres *et al.* [40]	The combination of BF >9 mon with a non-regular use of pacifiers, between 12 mon and 4 yr, were considered a protective factor.	Regular Pacifier use from 12 mon to 4 yr caused 3.6 more possibilities of developing an OB whereas thumb sucking at 6 yr induced 1.4 more risk of OB.	There was no interaction between the duration of BF and the use of Pacifier.
20	Peres *et al.* [41]	Exclusive BF decreased the prevalence of malocclusion.	Exclusive BF <6 mon and Pacifier use: Increased prevalence of OB and of moderate and severe malocclusions.	Exclusive BF had a protective effect on pacifier use.
21	Vasconcelos *et al.* [42]	/	OB was associated to NNSH.	/

NSH: Nutritive sucking habit; NNSH: Non-nutritive sucking habits; BF: Breastfeeding; OB: Open bite; ICD: Intercanine distance; IMD: Intermolar distance.

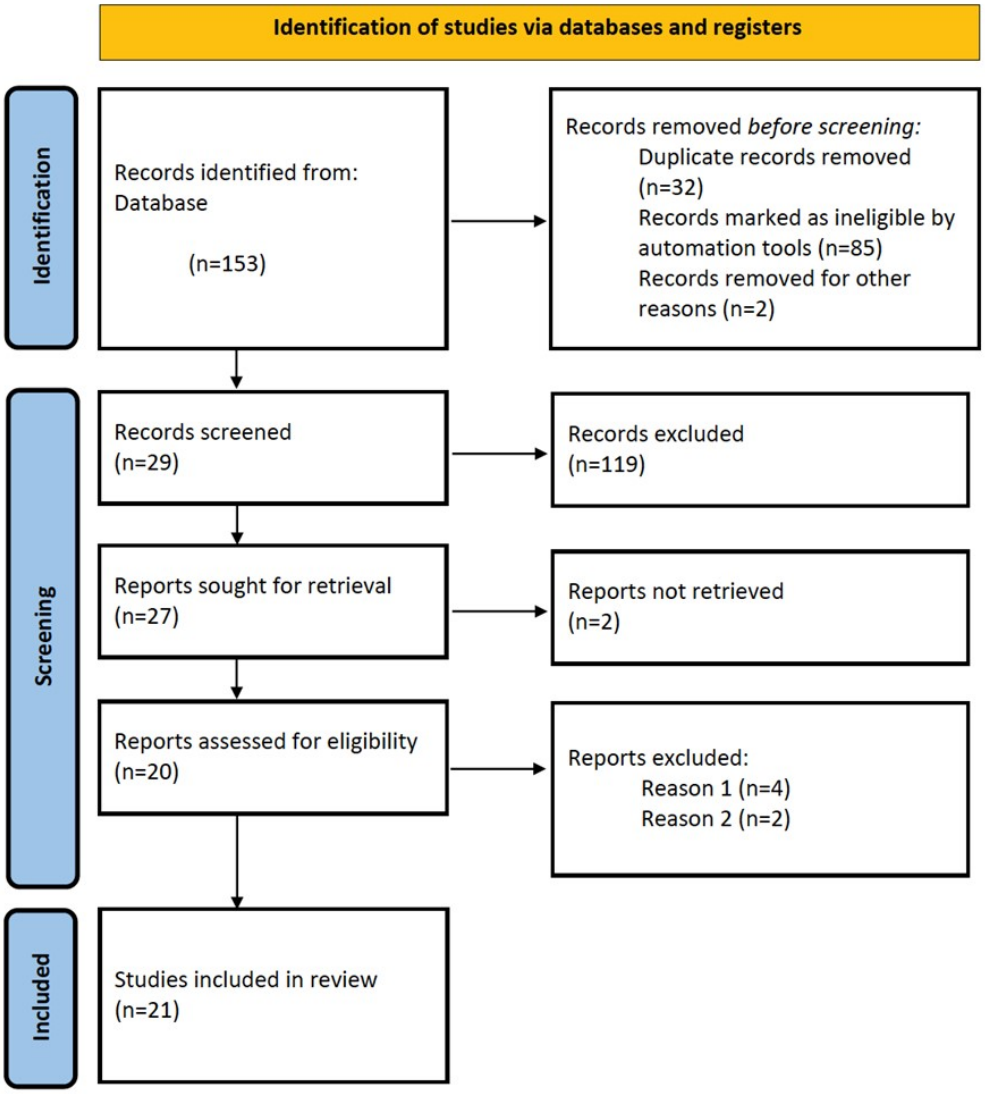

FIGURE 1. PRISMA. Flow diagram.

3.1 Characteristics of the studies

Fourteen cross-sectional studies [22–35] and seven cohorts [36–47] were identified. These studies were conducted in Brazil [23, 24, 27, 30, 33, 35, 39–42], China [22, 25, 32], USA [36, 38], India [26], Slovenia [28], Senegal [29], Puerto Rico [31] and Spain [34].

Children with primary dentition were investigated. According to the included studies, the age range of the participants varied between two and five years [20, 31, 34, 41], three and six years [24, 25, 27, 30, 34], four and five years [23, 36] and between five and six years [28, 29]. In two studies, researchers followed children from birth [40, 41], in one article from 6 months [30] and in another investigation from 12 months [37].

With regards to NSH and NNSH, one article assessed frequency [36], nine assessed the duration of NNSH and NSH [22–24, 26, 28, 34, 37, 39, 40] and in the remaining 11 studies, both factors were investigated [24, 25, 27, 29–33, 37, 39, 40]. Fourteen articles also assessed other variables, including socioeconomic level [22, 25, 30, 33, 35, 37–40] or the presence of oral respiration/the size of the nasal airways [23, 24, 28].

3.2 Risk of bias assessment

We identified average methodological and clinical homogeneity among the included studies. According to the JBI Critical Appraisal Checklist [19, 20], three cohort studies [39–41] and seven clinical trials [22, 24, 25, 34–36] were of good quality. The principal failures of the selected articles were (1) a lack of measurement of exposure to sucking habits in a valid and reliable manner, (2) a lack of identification of confounding factors (sociodemographic factors, social status, presence of other diseases), and (3) a lack of information on the follow-up time and whether it was long enough for malocclusions to occur. These results were illustrated in Tables 4 and 5.

3.3 Results of bias across studies

The GRADE system [21] was performed to assess the overall quality of the included studies. All transversal studies qualified as a very serious risk of bias and all analytical studies as a serious risk of bias. All articles provided confidence intervals for the effects of treatment and were scored as no serious risk for imprecision. We did not attribute negative punctuation for

TABLE 4. JBI critical appraisal checklist—cohort studies. Quality index.

Quality Index—JBI critical appraisal checklist for cohort studies								
		2014 Moimaz *et al.* [30]	2002 Warren *et al.* [36]	2003 Charchut *et al.* [38]	2012 Caramez da Silva *et al.* [39]	2007 Peres *et al.* [40]	2015 Peres *et al.* [41]	2011 Vasconcelos *et al.* [42]
Question 1	0 no, 1 yes	0	1	1	1	1	1	1
Question 2	0 no, 1 yes	1	1	1	1	1	1	1
Question 3	0 no, 1 yes	0	0	0	0	1	1	0
Question 4	0 no, 1 yes	0	0	0	1	1	1	0
Question 5	0 no, 1 yes	0	0	0	0	1	1	0
Question 6	0 no, 1 yes	1	1	1	1	1	1	1
Question 7	0 no, 1 yes	1	1	0	1	1	1	0
Question 8	0 no, 1 yes	0	0	1	0	0	1	0
Question 9	0 no, 1 yes	1	0	0	1	0	1	0
Question 10	0 no, 1 yes	0	0	1	1	0	0	0
Question 11	0 no, 1 yes	1	1	1	1	1	1	1
Total score		5	5	6	9	8	10	3
Quality		Poor	Poor	Fair	Good	Good	Good	Poor
		Good = 3; Fair = 1; Poor = 3						

inconsistency because there was no heterogeneity in the results of the selected studies. Investigations that had no statistically significant results and a low sample size were considered to feature publication bias.

Five studies [27, 31, 33, 34, 36] were considered to have a moderate quality of evidence and eleven studies [22–25, 28–30, 37, 42] had a low quality of evidence. The remaining articles [26, 34, 38, 40, 41] had a low quality of evidence. Quality assessment is summarized in Table 6.

3.4 Results specific analyses

3.4.1 NSHs and malocclusion

With regards to nutritive sucking habits, the studies by Sum *et al.* [22] and Bueno *et al.* [23] showed that a suckling child presented with a higher probability of having a correct overbite. Romero *et al.* [24] reported that the chances of diagnosing an anterior open bite were significantly higher for non-breastfed children when compared to those who were breastfed for periods longer than 12 months, even in children with no history of NNSH. An inverse relationship was reported between the duration of breastfeeding (BF) and the prevalence of open bite (OB) [38]. Subsequently, Kobayashi *et al.* [27] demonstrated a statistically significant relationship between the duration of exclusive BF and the prevalence of posterior crossbite. In the study by Melink *et al.* [28], comparisons of several questionnaire parameters regarding nutritive and non-nutritive sucking behaviors between the posterior crossbite and non-crossbite groups of children showed no statistically significant differences in terms of the duration of breastfeeding and bottle feeding.

Breastfeeding provides protection against distoclusion [39] and a longer duration of breastfeeding was associated with a higher probability of a Class I incisal pattern [23, 25, 26, 30].

TABLE 5. JBI critical appraisal checklist—cross-sectional studies. Quality index.

Quality Index—JBI critical appraisal checklist for cross-sectional studies															
		2015 Sum *et al.* [22]	2013 Bueno *et al.* [23]	2011 Romero *et al.* [24]	2016 Chen *et al.* [25]	2014 Agarwal *et al.* [26]	2010 Kobayash *et al.* [27]	2010 Melink *et al.* [28]	2010 Diouf *et al.* [29]	2006 López Del Valle *et al.* [31]	2018 Ling *et al.* [32]	2020 Traebert *et al.* [33]	2015 Lopes-Freire *et al.* [34]	2018 Da Costa *et al.* [35]	2011 Jabbar NSA *et al.* [37]
Question 1	0 no, 1 yes	1	0	1	1	1	1	0	1	0	1	0	1	1	1
Question 2	0 no, 1 yes	0	1	1	1	0	0	0	0	1	0	1	0	1	0
Question 3	0 no, 1 yes	0	1	1	1	1	0	0	0	0	0	0	0	1	1
Question 4	0 no, 1 yes	1	0	1	1	1	1	1	1	0	1	1	1	1	1
Question 5	0 no, 1 yes	1	0	1	1	1	0	0	1	0	0	0	1	0	0
Question 6	0 no, 1 yes	1	0	0	0	1	1	0	0	0	0	0	0	0	0
Question 7	0 no, 1 yes	1	0	1	1	1	0	1	0	0	1	1	1	1	1
Question 8	0 no, 1 yes	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total score		6	3	7	7	7	4	3	4	2	4	4	5	6	5
Quality		Good	Poor	Good	Good	Good	Fair	Poor	Fair	Poor	Fair	Fair	Good	Good	Good
Good = 7; Fair = 3; Poor = 4															

TABLE 6. The GRADE system [21].

Quality assessment				Summary of findings		
				N° of patients		Absolute risk
N° of studies (design)	Risk of Bias	Imprecision	Publication bias	With Maloclusion	Without Maloclusion	Quality
Presence of malocclusion when child has NSH						
4 (21; 29; 35; 36)	Very Serious	No Serious	Very Likely	2041	1384	⊕OOO Very low
2 (17; 32)	Very Serious	No Serious	Likely	578	1184	⊕⊕OO Low
1 (24)	Serious	No Serious	Very Likely	226	19	⊕⊕OO Low
3 (22; 26; 31)	Serious	No Serious	Likely	426	2189	⊕⊕⊕O Moderate
Presence of malocclusion when child has NNSH						
1 (33)	Very Serious	No Serious	Very Likely	642	214	⊕OOO Very low
2 (19; 20)	Very Serious	No Serious	Likely	977	1230	⊕⊕OO Low
6 (18; 23; 24; 25; 32; 37)	Serious	No Serious	Very Likely	697	167	⊕⊕OO Low
2 (28; 29)	Serious	No Serious	Likely	1477	1003	⊕⊕⊕O Moderate

NSH: Nutritive sucking habit; NNSH: Non-nutritive sucking habits.

3.4.2 NNSHs and malocclusions

With regards to NNSHs, several authors [24, 32, 33] observed that children with daily pacifier (PSH) or finger (FSH) sucking habits were significantly more likely to develop an anterior open bite. Furthermore, persistent NNSHs were significantly associated with increased chances of having an OB and decreasing DB [24, 33, 36]. Furthermore, the duration of pacifier use was identified as an indicator of CB risk. Thus, the longer the duration of the pacifier habit, the greater the probability of posterior crossbite [23, 28]. However, it is important to note that in three studies, no statistically significant association was observed between NNSH and the prevalence of posterior crossbite, nor with the development of intercanine/intermolar distance [26, 32, 36]. NNSHs were significantly associated with increased protrusion and a Class II primary canine relationship [23, 34, 38].

3.4.3 Relationship between nutritive and non-nutritive sucking habits

The concomitant presence of exclusive breastfeeding with a duration of less than six months and the use of pacifiers up to 48 months-of-age increased the prevalence of moderate/severe malocclusion [40]. According to Peres *et al.* [41], the concomitant presence of breastfeeding for at least nine months and a low frequency of pacifier use between twelve months and four years-of-age is necessary to ensure a protective effect on malocclusion.

However, it is important to understand that the duration of BF has an influence on the probability of a prolonged pacifier sucking habit, but not on finger sucking [25].

3.4.4 Other variables

We also observed the existence of other variables, such as the socioeconomic status of the children and the presence of oral respiration; these factors influenced the presence of habits and the development of malocclusions. First, Peres *et al.* [41] showed that when breastfeeding was predominant, there was a significantly lower prevalence of malocclusions that were independent of demographic, socioeconomic, anthropometric and anthropometric factors and respiratory diseases related to oral health. However, maintaining the same conditions, but adding the pacifier habit up to 48 months, statistical significance was lost [40, 41]. With regards to oral breathing, mouth-breathing children could develop a functional disorder referred to as atypical tongue positioning, which could lead to a marked buccal inclination of the maxillary and mandibular incisors and result in several diastemas in the anterior region [33, 37].

4. Discussion

Recent studies [22–28, 30, 39] corroborated the results found in this systematic review on the chances of presenting transverse, sagittal and vertical malocclusions in children with NNSH and

in children who were breastfed for less than six months or with a bottle-feeding habit.

4.1 Breast-feeding *vs.* bottle-feeding

Exclusive breastfeeding between zero and six months is advised by the World Health Organization (WHO) as a public health policy because it reduces the risk of aero-digestive infections. Breastfeeding is defined as one of the foundations of health promotion and the prevention of many diseases and is one of the pillars of correct maxillofacial growth because it favors proper lip sealing, jaw function and the position of the tongue against the palate [43]. Indeed, breastfeeding forces the child to actively extract milk from the mother's breast through the synergistic action of the tongue and facial muscles [7, 44–48]. In opposition, bottle feeding requires less effort to drain the milk, so it does not stimulate the functional matrix and favors the development of malocclusions such as a posterior crossbite, anterior open bite, increased protrusion and a class II molar and canine relationship. Similarly, the bottle nipple is usually made of a less flexible material, which can press inside the oral cavity and lead to improper alignment of the teeth and a narrow palate [43]. Furthermore, according to several authors [6, 22, 49–53], children with a bottle favor a strong tendency to develop a pacifier habit.

4.2 NNSHs

In some developed countries, the use of pacifiers is so culturally established that the prevalence in young children at 12 months can be as high as 42.5%. Pacifier sucking is the most common NNSH and has received considerable research attention for many years [54]. The use of pacifiers can be a dangerous factor in the development of malocclusions. Indeed, the three factors that are associated with the relationship of malocclusion and pacifier use are intensity, frequency and duration of pacifier use. The recommended age for stopping the pacifier sucking habit is two years, and this is considered a prolonged habit if continued pacifier use lasts until four years of age or more [54]. In most cases, this habit stops spontaneously at around five years-of-age. However, in a minority of cases, the habit may continue for several more years, even into adolescence and beyond [55, 56]. This habit can induce deformity of the dental occlusion, and this deformity is produced in direct proportion to the parameters of the presence of the habit [55, 57–60]. The longer the duration of the force (50% of the time), the greater its impact on teeth. Thus, to produce significant variability in tooth position, durations should be measured in hours per day. There is clear evidence that sucking habits in children are strongly correlated with malocclusions [5].

4.3 Limitations

Arguably, having followed the PRISMA method, there were no limitations in the methodology of this systematic review. Methodological and mean clinical homogeneity was detected among the studies. According to the JBI Critical Appraisal Checklist [19, 20], in the cohort studies, three studies [39, 41] were found to be of good quality. In the clinical trial studies, there were seven [22, 24–26, 34–36] articles of good quality. The main failures of the selected articles were as follows. First, the lack of exposure measurement in a valid and reliable way: questionnaires were sent to parents and referred to a child's nutritive and NNSHs and a clinical examination of the child or on its cast model were performed. The included studies did not specify the reference test used. In some articles, the authors mentioned that in the questionnaires, parents and surrogate informants could be mistaken about feeding habits or answer the option that they considered correct to please the interviewer. Secondly, the lack of identification of confounding factors (sociodemographic factors, social status and the presence of other diseases). Third, the lack of information on the follow-up time of the population and whether this time was sufficient for the results to be produced: The follow-up of the dental condition is important as it can provide information associated with the age of onset of the malocclusion or whether the malocclusion was self-corrected at the time of the final examination. In addition, it is important to mention the large heterogeneity between the sample sizes of each study. The sample size varied from 60 children to 1377 children. This hindered the comparability of the results. Similarly, there was much disparity in the age of the study participants.

5. Conclusion

We identified an association between NNSHs and the development of malocclusions, including anterior open bite, posterior crossbite, increased protrusion and Class II primary canine relationship. The duration of habits has a negative influence on the occurrence of defects in dental occlusion.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article (and supplementary material).

AUTHOR CONTRIBUTIONS

CS, LT and LA—designed the research study and performed the literature search and data analysis. CS—wrote the manuscript. CR, IDR, INS and PMPS—helped with the manuscript and drafted and/or critically revised the work. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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