

RESEARCH

Open Access



Associations between oral habits and specific malocclusion traits in children: a retrospective cross-sectional study in Italy

Marco Severino¹, Antonella Mattei², Filippo Vena³, Arianna Viarchi^{2*}, Claudia Theodora Truppa², Guido Lombardo¹, Riccardo Carullo¹, Debora Cialfi², Lisa Bertini¹ and Stefano Cianetti¹

Abstract

Background Several factors, including feeding methods, food texture and oral habits, are closely associated with malocclusions. This study aimed to assess the associations between malocclusion and oral habits in Italian children aged 6–12 years.

Methods A retrospective cross-sectional epidemiological study was conducted on a sample of 190 children in the University Dental Clinic of Perugia, Italy, between January 2023 And January 2024. Medical records, complete with questionnaires and clinical dental examinations, were used to analyze the presence of malocclusions and their associations with oral habits (breastfeeding, bottle feeding, pacifier use, finger sucking, dysfunctional swallowing, mouth breathing, onychophagy, object biting, and short lingual frenulum). The participants were divided into two groups: with and without malocclusion. Children with malocclusion were further categorized into subgroups on the basis of Angle's classification (Class I/II/III), overjet (normal/increased/reversed), and overbite (normal/deep/open).

Results Among 190 evaluated patients, 72.26% presented with malocclusion. Of these patients, 39.47% had Class II or Class III malocclusions (31.05% And 8.42%, respectively). An increased overjet was observed in 44.21% of the patients, whereas 3.16% exhibited a reverse overjet. An open bite was present in 15.26% of the samples, whereas a deep bite was observed in 33.16%. Among the most common oral habits, dysfunctional swallowing was significantly associated with all the malocclusions observed. The relative risk ratio of having a class II or a class III dental class was greater for those who presented dysfunctional swallowing (RRR 4.24, 95% CI 1.51–11.88, $p=0.006$) and (RRR 10.17, 95% CI: 1.14–80.60, $p=0.038$), respectively, compared with Class I. Similarly, the presence of dysfunctional swallowing increases the risk of having an increased overjet (RRR of 5.85, 95% CI: 2.23–15.36, $p<0.001$) and opening overbite (RRR of 10.82 95% CI: 1.28–90.97, $p=0.028$). The risk of malocclusion increases with the number of harmful oral habits present.

Conclusion This study revealed an association between different types of malocclusion and oral habits. Multinomial logistic regression analysis identified dysfunctional swallowing as an independent risk factor for Class II and III malocclusions, increased overjet and open bite. This study emphasizes the cumulative impact of oral habits on

*Correspondence:
Arianna Viarchi
arianna.viarchi@student.univaq.it

Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

malocclusion. Ongoing monitoring and multidisciplinary assessments are crucial for improving prevention and treatment. These findings highlight the potential clinical relevance of early identification and implementation of preventive strategies.

Keywords Malocclusion, Oral habits, Epidemiology, Childhood

Introduction

Malocclusion is a misalignment of teeth associated with altered occlusal contact and a disharmonious relationship between the maxillary bones, resulting in a lack of ideal function of the masticatory apparatus (Paglia et al.) [44].

According to the WHO, malocclusion is the second most prevalent oral disease in children (after caries) and the third most prevalent oral disease in adults (after caries and periodontal diseases). Malocclusion affects approximately one in two (56%) adolescents or children worldwide and arises in the deciduous dentition. This disease, when left untreated and persists into the permanent dentition because it does not resolve spontaneously with body growth [38].

Malocclusion should be detected early and appropriately addressed, particularly in children, as it impacts essential oral functions such as chewing, swallowing, speaking and breathing [63]. Over the years, dentistry has focused not only on therapies to resolve malocclusions but also on methods to prevent them [47]. Prevention is based on both the detection and removal of malocclusion risk factors to avoid the onset or progression of this disease [61]. In the literature, several types of children's oral habits have been described as risk factors for malocclusions, the most frequently mentioned of which are 'nonnutritive sucking habits' (NNSHs), such as pacifiers, thumb/digit sucking, and a reduced duration of breastfeeding (less than 6 months), followed by baby bottle feeding mouth breathing and atypical swallowing [12] [56]. The prevalence of oral habits varies and depends on many factors, such as age and location [52].

These oral habits could be related to malocclusion due to their potential to affect chewing, swallowing, and breathing during childhood, which is a critical period for maxillary bone growth and the eruption of teeth in the dental arches [27, 30, 34, 36]. Such functional alterations can influence the correct development of the maxilla and the spatial arrangement of teeth, contributing to the onset of malocclusions.

In addition, these oral habits may affect tongue position, causing it to adopt a low posture both during swallowing and at rest. This low lingual posture often results in a lack of upward thrust against the palate and an imbalance between lingual and cheek-lip pressures. Over time, this imbalance can lead to a reduction in the transverse diameter of the upper maxilla and a lack of space

for the proper linear alignment of teeth in the upper arch [27],[39]

While several studies have explored the relationship between oral habits and malocclusion, few have examined the cumulative impact of multiple habits using a clinical sample from a real-world setting. The aim of this study was to describe the relationships between malocclusion (including its main forms, such as Class II and III malocclusion, increased or reversed overjet and altered overbite) and the most relevant oral habits (breastfeeding, bottle feeding, pacifier use, thumb/digit sucking, dysfunctional swallowing and mouth breathing) in a sample of children aged 6–12 years in Umbria, Italy.

Methods

Study design and sample section

A retrospective cross-sectional study was conducted on a sample of children who continuously attended the Pediatric Dental Clinic of the University of Perugia (Italy) for a first dental examination between January 2023 and January 2024. This epidemiologic investigation was carried out in accordance with the ethical principles for human research outlined in the Declaration of Helsinki and Good Clinical Practice (GCP) guidelines [10]. The study was approved by the Regional Ethics Committee of Umbria (protocol number CE-1501/24, dated 18/12/2024).

As the study was conducted within a university dental clinic, the characteristics of the sample may reflect, to some extent, the specific clinical context in which the data were collected.

Eligibility criteria

Children aged 6–12 years were included regardless of sex, citizenship status, family income or geographical origin. Subjects who had previously undergone orthodontic or speaking therapies were excluded. Individuals with genetic or syndromic diseases affecting maxillary growth and/or functions as well as tooth development in terms of both shape and number were also excluded. Moreover, participants with unclear data reported in the clinical records or without signed informed consent by the parents or the guardians were not included.

Study variables

Dependent variables: Presence of malocclusion and its subtypes: Angle classification (Classes I, II and III),

overjet (normal vs. increased or reversed) and overbite (normal vs. open or deep).

The independent variables included personal data (age, sex) and oral habits, such as breastfeeding, bottle feeding, pacifier use, thumb/digit sucking, dysfunctional swallowing, mouth breathing, onychophagy, lispiphagia and short lingual frenulum. Oral habits were analyzed as a dichotomous variable: present (yes) or absent (not).

Data collection

Data were extracted from medical records archived at the University Dental Clinic of Perugia between December 2024 And March 2025. Each record included data collected by two qualified dentists with more than 20 years of clinical practice and with substantial level of agreement in the malocclusion diagnosis (Cohen's kappa=0,93), during both the clinical visit and the anamnesis with the child's parents or guardians. The anamnesis, carried out through the administration of the questionnaire, collected demographic data and information on oral habits potentially linked to malocclusion, including onychophagia and lispiphagia.

Breastfeeding was considered present if continued until six months of age, while bottle feeding was considered positive if continued beyond one year of age. Pacifier use was considered present if continued beyond two years of age.

Moreover, the diagnosis of malocclusion and of the remaining oral habits, such as impaired swallowing, mouth breathing and short lingual frenulum, were carried out through an objective oral examination and specific tests. In particular, dysfunctional swallowing was diagnosed following the criteria published by Lawlor et al., 2020, whereas short lingual frenulum was diagnosed via the protocol published by Marchesan 2012; finally, mouth breathing was diagnosed via the Gaudin maneuver and the Rosenthal test [57].

All the collected clinical data were organized into a master table, dividing patients into two primary groups: those with or without malocclusion. Children with malocclusions were further categorized into subgroups on the basis of the specific type of diagnosed malocclusion. Since some patients exhibited more than one type, they could belong to multiple subgroups simultaneously. The questionnaire is reported in Appendix 1.

Statistical analysis

Descriptive statistics were used to summarize the characteristics of the sample through absolute and relative frequencies for categorical variables and mean values with standard deviations (SDs) for continuous variables. The presence/absence of malocclusion was used to stratify the sample into two groups. The statistical significance of pair comparisons was analyzed via the χ^2 test for

qualitative variables and the two-sample Wilcoxon rank-sum (Mann-Whitney) test for quantitative variables.

The significantly different variables between the two groups ($p < 0.05$) were introduced into a multivariate logistic regression model to identify independent factors associated with malocclusion, reported as odds ratios (ORs) And 95% confidence intervals (CIs). The absence of malocclusion was chosen as the reference category. This model was corrected for age and sex.

Backward stepwise selection with the Akaike information criterion (AIC) was used to choose the best logistic regression model. Statistical significance was set at $p < 0.05$.

The Dental Classes (I, II, III) Overjet (Normal, Increased and Inverted) and Overbite (Normal, Open, Closed) were used to stratify the samples into three groups. The differences among these three categories were assessed with the χ^2 test for categorical variables and Kruskal-wallis test for quantitative variables. When the resulting differences were statistically significant, post hoc analysis for the comparison of several values was performed via the χ^2 test, with adjustments for multiple comparisons of Bonferroni, and significance for pairwise comparisons was thus assessed at $p > 0.0125$.

Independent variables with p values < 0.25 in the univariate analysis were kept in a multinomial logistic regression model, according to the Zhongheng Zhang strategy (Z. Zhang., 2016), to identify the factors independently associated with malocclusions presented as relative risk ratios (RRRs) with 95% confidence intervals (95% CIs), corrected for age and sex. We used normal Dental Class I, Overjet and Overbite as the reference category; thus, in this study, Dental Class II and III were compared on the basis of Dental Class (I), Overjet Increased and Inverted with Normal and Overbite Open and Closed with Normal Overbite.

A chi-square test of independence was performed to assess the association between the number of oral habits (categorized as 0–1, 2–3, and > 3) and the presence of malocclusions.

The sample size was estimated with reference to the primary point of the study, which aims to detect An average effect size of 0.53 for the presence of Malocclusion between two groups. An analysis using Cohen's conventions performed with G power software, with a power greater than 90% ($1 - \beta$) and a level of significance $\alpha = 0.05$, identified An estimate of the sample size for a cross-sectional design of at least 142 participants in the malocclusion group And 46 participants in the non-malocclusion group.

Statistical significance was set at $p < 0.05$. The data were processed via the STATA/BE 18.0 statistical package.

Results

Among the 193 clinical records collected in the dental clinic, 190 (98%) presented data suitable for this study, while 3 were eliminated. Among them, two were excluded because parents did not give their authorization

Table 1 Descriptive analysis of sample characteristics, stratified by presence or absence of malocclusions

Variables	Total	MALOCCCLUSION		p value
	N=190	Absence n (%)	Presence n (%)	
		47 (24.74)	143 (75.26)	
Age (Years), media ± SD	8.58 ± 2.05	8.66 ± 1.91	8.56 ± 2.09	0.699*
Sex , n (%)				0.557
Male	96 (50.53)	22 (46.81)	74 (51.75)	
Female	94 (49.47)	25 (53.19)	69 (48.25)	
Breastfeed- ing , n (%)				0.113
No	49 (25.79)	8 (17.02)	41 (28.67)	
Yes	141 (74.21)	39 (82.98)	102 (71.33)	
Feeding bottle , n (%)				0.135
No	75 (39.68)	23 (48.94)	52 (36.62)	
Yes	114 (60.32)	24 (51.06)	90 (63.38)	
Pacifier , n (%)				0.064
No	99 (52.11)	30 (63.83)	69 (48.25)	
Yes	91 (47.89)	17 (36.17)	74 (51.75)	
Finger , n (%)				0.710
No	157 (82.63)	38 (80.85)	119 (83.22)	
Yes	33 (17.37)	9 (19.15)	24 (16.78)	
Onychoph- agy , n (%)				0.484
No	164 (86.32)	42 (89.36)	122 (85.31)	
Yes	26 (13.68)	5 (10.64)	21 (14.69)	
Lapispha- gia , n (%)				0.904
No	173 (91.05)	43 (91.49)	130 (90.91)	
Yes	17 (8.95)	4 (8.51)	13 (9.09)	
Dysfunc- tional swallowing , n (%)				<0.001
No	50 (26.32)	27 (57.45)	23 (16.08)	
Yes	140 (73.68)	20 (42.55)	120 (83.92)	
Oral respi- ration , n (%)				<0.001
No	103 (55.98)	36 (76.60)	67 (48.91)	
Yes	81 (44.02)	11 (23.40)	70 (51.09)	
Short phrenulum , n (%)				0.536
Yes	156 (82.11)	40 (85.11)	116 (81.12)	
No	34 (17.89)	7 (14.89)	27 (18.88)	

* Two-sample Wilcoxon rank-sum (Mann–Whitney) test

χ^2 test

to use the data, And the other was excluded because the data were incomplete. Among the 190 (96 males; 50.53% And 94 females; 49.47%) evaluated patients, 143 (75.26%) were affected by malocclusion.

No significant differences in age ($p=0.699$) or sex ($p=0.557$) were detected between the two groups. Given the homogeneity of the two groups by age and sex, these observations presumably indicate that the sociodemographic characteristics do not constitute confounding variables for a successful comparison of the two groups.

Statistically significant differences emerged between the two groups regarding the presence of dysfunctional swallowing and oral respiration, and these variables were greater in the group with malocclusion, 83.92% vs. 42.55% ($p<0.001$) for dysfunctional swallowing And 51.09% vs. 23.40% ($p<0.001$) for oral respiration (Table 1).

>

According to the multivariate logistic model adjusted for age and sex, dysfunctional swallowing emerged as an independent risk factor associated with the presence of malocclusion (OR: 5.94, CI: 2.49–14.21; $p=0.014$) (Table 2).

All subgroups of malocclusions were analyzed and compared with all spoiled habits. Statistically significant associations are reported.

When the dental classes were compared with all spoiled habits, a significant overall difference emerged for dysfunctional swallowing ($p<0.001$), oral respiration ($p=0.026$) and short phrenulum ($p=0.031$). Post hoc pairwise comparisons of the dental classes revealed statistically significant differences in dysfunctional swallowing, oral respiration And short frenulum. The dental class I And dental class II values were significantly lower in group I than in group II: 62.61 vs. 89.83, $p<0.001$; 36.04 vs. 56.90, $p=0.009$; And 13.04 vs. 28.81, $p=0.011$, respectively. The values of dysfunctional swallowing were significantly different between dental classes I and III (62.61 vs. 93.75, $p=0.013$) (Table 3).

We performed a multinomial logistic regression analysis to explain the relationship between dental class categories and the variables that significantly differed among them. We used Dental Classes I as the baseline category. The relative risk ratio of having a class II or a class III dental class was greater for those who presented dysfunctional swallowing (RRR 4.24, 95% CI 1.51–11). 88, $p=0.006$) and (RRR 10.17, 95% CI 1.14–90.60, $p=0.038$), respectively (Table 4).

Statistically significant differences emerged among the three groups (overjet) regarding dysfunctional swallowing ($p<0.001$) and oral respiration ($p<0.001$). Post hoc Analysis for pairwise comparison of Overjet classes revealed statistically significant differences in Dysfunctional swallowing And Oral respiration. Dysfunctional swallowing and Oral respiration values were significantly

Table 2 Multivariate logistic regression analysis of the risk factors for malocclusion

	Univariate Logistic Model OR	CI 95%	p value	Multivariate Logistic Model OR*	CI 95%	p value
Dysfunctional swallowing						
No	1			1		
Yes	7.04	3.39-14.62	<0.01	5.94	2.49- 14.21	0.014
Oral respiration						
No	1					
Yes	3.42	1.60-7.27	0.001			

Odds Ratio* Corrected for age and sex
AIC=189

Table 3 Descriptive analysis of sample characteristics, stratified by dental class (I, II, III)

Variables	Total N= 190	DENTAL CLASS			p value
		I n (%)	II n (%)	III n (%)	
Age (Years), mean ± SD	8.58 ± 2.05	115 (60.53) 8.59 ± 1.95	59 (31.05) 8.59 ± 2.20	16 (8.42) 8.5 ± 2.25	0.961*
Sex , n (%)					0.795**
Male	96 (50.53)	56 (48.70)	31 (52.24)	9 (56.25)	
Female	94 (49.47)	59 (51.30)	28 (47.46)	7 (43.75)	
Breastfeeding , n (%)					0.789**
No	49 (25.79)	30 (26.09)	16 (27.12)	3 (18.75)	
Yes	141 (74.21)	85 (73.91)	43 (72.88)	13 (81.25)	
Feeding bottle , n (%)					0.968**
No	75 (39.68)	46 (40.35)	23 (38.98)	6 (37.50)	
Yes	114 (60.32)	68 (59.65)	36 (61.02)	10 (62.50)	
Pacifier , n (%)					0.420**
No	99 (52.11)	63 (54.78)	30 (50.85)	6 (37.50)	
Yes	91 (47.89)	52 (45.22)	29 (49.15)	10 (62.50)	
Finger , n (%)					0.286**
No	157 (82.63)	99 (86.08)	46 (77.97)	12 (75.00)	
Yes	33 (17.37)	16 (13.91)	13 (22.03)	4 (25.00)	
Onychophagy , n (%)					0.763***
No	164 (86.32)	100 (86.96)	51 (86.44)	13 (81.25)	
Yes	26 (13.68)	15 (13.04)	8 (13.56)	3 (18.75)	
Lapisphagia , n (%)					0.923***
No	173 (91.05)	105 (91.30)	53 (89.83)	15 (93.75)	
Yes	17 (8.95)	10 (8.70)	6 (10.17)	1 (6.25)	
Dysfunctional swallowing ,n (%)					< 0.001***
No	50 (26.32)	43 (37.39)	6 (10.17)	1 (6.25)	
Yes	140 (73.68)	72 (62.61)	53 (89.83)	15 (93.75)	
Oral respiration , n (%)					0.026**
No	103 (55.98)	71 (63.96)	25 (43.10)	7 (46.67)	
Yes	81 (44.02)	40 (36.04)	33 (56.90)	8 (53.33)	
Short phrenulum , n (%)					0.031***
No	156 (82.11)	100 (86.96)	42 (71.19)	14 (87.50)	
Yes	34 (17.89)	15 (13.04)	17 (28.81)	2 (12.50)	
Post hoc analysis					
	I vs. II	I vs. III	II vs. III		
Dysfunctional swallowing	<0.001	0.013	0.633		
Oral respiration	0.009	0.195	0.804		
Short phrenulum	0.011	0.952	0.183		

SD: Standard deviation; *F: Kruskal-wallis; ** χ^2 test; ***Fisher's test
Post hoc: χ^2 test correct using by Bonferroni adjustment, $p < 0.0125$

Table 4 Estimated relative risk ratios of presenting II or III dental class by multinomial logistic regression

	Dental Class			
	Dental class II		Dental class III	
	RRR (95% CI)	p value	RRR (95% CI)	p value
Dysfunctional swallowing	1	0.006	1	0.038
No ^a	4.24		10.17	
Si	(1.51–11.88)		(1.14–90.60)	
Oral respiration	1	0.409	1	0.924
No ^a	1.36		0.94	
Si	(0.65–2.84)		(0.29–3.04)	
Short phrenulum	1	0.132	1	0.649
No ^a	1.88		0.68	
Si	(0.82–4.31)		(0.13–3.46)	

^a reference category

RRR: Relative risk ratio corrected for age and sex

lower in the Overjet Normal group than in the Overjet Increased group: 58.00% vs. 91.67%, $p < 0.001$; And 30.53% vs. 59.04%, $p = 0.001$, respectively. Dysfunctional swallowing And oral respiration values were significantly lower in the Overjet Normal group than in the Inverted group: 58.00% vs. 83.33%, $p < 0.001$; And 30.53% vs. 50.00%, $p = 0.005$, respectively (Table 5).

We performed a multinomial logistic regression analysis to explain the relationship between Overjet categories and the variables that significantly differed among them. Statistically significant differences emerged among the three groups regarding dysfunctional swallowing ($p < 0.001$) and oral respiration ($p < 0.001$). We used normal objects as the baseline category. The relative risk ratio of having an increased overjet was greater for those who presented dysfunctional swallowing (RRR 5.85, 95% CI 2.23–15.36, $p < 0.001$) (Table 6).

Statistically significant differences emerged among the three groups (Overbite) regarding dysfunctional swallowing ($p = 0.003$) and oral respiration ($p = 0.026$).

Dysfunctional swallowing And oral respiration values were significantly lower in the Overbite Normal group than in the Overbite Open group: 65.31% vs. 96.55%, $p = 0.001$; 37.50% vs. 66.67%, $p = 0.007$, respectively (Table 7).

We performed a multinomial logistic regression analysis to explain the relationships between Overbite categories and the variables that significantly differed among them. We used normal overbite as the baseline category. The relative risk ratio of having an Overbite Open was greater for those who presented Dysfunctional swallowing (RRR 10.82, 95% CI 1.28–90.97, $p = 0.028$) (Table 8).

Finally, the samples were divided into three groups according to the number of oral habits present in each patient (0–1, 2–3, > 3). This classification made it possible

to analyze the association between the number of oral habits and the presence of malocclusions (Table 9).

The data analysis revealed that there was a strong and significant association between the number of oral habits and the presence of malocclusions ($p < 0.001$).

Discussion

This study investigated the associations between malocclusions (both in general and in various forms) And the most common oral habits in a sample of Italian children aged 6–12 years who were examined at the University Dental Clinic of Perugia.

One of the main findings was the high prevalence of malocclusion, which affects four out of five children. Among the different types of malocclusions, Angle's Class II, increased overjet, And open bite were the most frequently observed, each affecting nearly one-third of the sample. In contrast, reverse overjet was the least common, occurring in only 3% of the samples. These results are consistent with previous studies reporting a European average malocclusion prevalence of approximately 72% [38].

It should be noted that this relatively high prevalence may, at least in part, reflect the characteristics of the clinical population attending a university dental clinic, and may not be fully generalizable to the broader pediatric population.

The most prevalent oral habits identified in our study were dysfunctional swallowing and breastfeeding during the first months of life, both of which affect approximately three out of four children. Notably, bottle feeding (which could be considered an alternative to breastfeeding) was also highly prevalent, affecting approximately half of the children, suggesting that many children were exposed to both types of feeding during different stages of development or used bottles to consume fluids other than milk.

Pacifier use is more socially visible and culturally accepted, especially in infancy [56]. As a tangible object, it is more easily observed And regulated by caregivers And endorsed by clinical guidelines such as those from the AAPD, which consider it acceptable in the first 2–3 years of life [18]. In contrast, finger sucking is often a private, self-soothing behavior that may go unnoticed And can persist longer if not addressed. Our sample included children aged 6–12 years, many of whom may have stopped these habits years earlier. While pacifier use typically ends by age 4, finger sucking may continue into school (Moimaz, 2022). Thus, the lower prevalence of finger sucking may reflect underreporting or early resolution, whereas pacifier use is more likely to be remembered and reported. Overall, the higher frequency of pacifier use in our study likely reflects both real

Table 5 Descriptive analysis of sample characteristics, stratified by overjet (Normal, increased and Inverted)

Variables	Total N = 190	Overjet			p value
		Normal n (%)	Increased n (%)	Inverted n (%)	
Age (Years), mean ± SD	8.58 ± 2.05	8.43 ± 2.01	8.74 ± 2.10	8.83 ± 2.14	0.558*
Sex, n (%)					0.428**
Male	96 (50.53)	55 (55.00)	38 (45.24)	3 (50.00)	
Female	94 (49.47)	45 (45.00)	46 (54.76)	3 (50.00)	
Breastfeeding, n (%)					0.274**
No	49 (25.79)	23 (23.00)	23 (27.38)	3 (50.00)	
Yes	141 (74.21)	77 (77.00)	61 (72.62)	3 (50.00)	
Feeding bottle, n (%)					0.275**
No	75 (39.68)	44 (44.44)	30 (35.71)	1 (16.67)	
Yes	114 (60.32)	55 (55.56)	54 (64.29)	5 (83.33)	
Pacifier, n (%)					0.244**
No	99 (52.11)	54 (54.00)	44 (52.38)	1 (16.67)	
Yes	91 (47.89)	46 (46.00)	40 (47.62)	5 (83.33)	
Finger, n (%)					0.361**
No	157 (82.63)	85 (85.00)	68 (80.95)	4 (66.67)	
Yes	33 (17.37)	15 (15.00)	16 (19.05)	2 (33.33)	
Onychophagy, n (%)					0.734**
No	164 (86.32)	87 (87.00)	71 (84.52)	6 (100.00)	
Yes	26 (13.68)	13 (13.00)	13 (15.48)	0 (00.00)	
Lapisphagia, n (%)					0.610**
No	173 (91.05)	91 (91.00)	77 (91.67)	5 (83.33)	
Yes	17 (8.95)	9 (9.00)	7 (8.33)	1 (16.67)	
Dysfunctional swallowing, n (%)					< 0.001**
No	50 (26.32)	42 (42.00)	7 (8.33)	1 (16.67)	
Yes	140 (73.68)	58 (58.00)	77 (91.67)	5 (83.33)	
Oral respiration, n (%)					< 0.001**
No	103 (55.98)	66 (69.47)	34 (40.96)	3 (50.00)	
Yes	81 (44.02)	29 (30.53)	49 (59.04)	3 (50.00)	
Short phrenulum, n (%)					0.162**
No	156 (82.11)	87 (87.00)	64 (76.19)	5 (83.33)	
Yes	34 (17.89)	13 (13.00)	20 (23.81)	1 (16.67)	
Post hoc analysis					
	Normal vs. Increased	Normal vs. Inverted	Increased vs. inverted		
Dysfunctional swallowing	<0.001	<0.001	0.013		
Oral respiration	0.001	0.005	0.061		

SD: Standard deviation; *F: Kruskal-wallis; ** Fisher's test; *** χ^2 test.Post hoc: χ^2 test correct by Bonferroni, $p < 0.0125$

behavioral patterns and reporting biases linked to age and visibility.

Focusing on the primary objective of the study, which was to assess the relationship between oral habits and malocclusion, only two habits, dysfunctional swallowing and mouth breathing, were significantly associated with altered dental occlusion. These results are in line with recent literature. Specifically, a recent meta-analysis published in 2024 by Gómez-González identified dysfunctional swallowing as a risk factor for malocclusions in general and for specific types, such as Angle Class II malocclusions (distocclusions), open bites, and increased

overjet (Gómez-González C.)[28]. These three types of malocclusion were also described in our study as being related to dysfunctional swallowing, with the only difference being that our analysis also revealed an association with Angle's Class III malocclusion.

A possible explanation for the relationship between Class III malocclusion and dysfunctional swallowing may be that a low tongue posture during swallowing could exert pressure on the oral side of the mandibular symphysis, pushing the mandible forward. This hypothesis underlies some specific treatments for nongenetic Class III malocclusions (Zhou X. et al.)[63], which involve

Table 6 Estimated relative risk ratios of presenting overjet increased or inverted by multinomial logistic regression

	Overjet			
	Increased		Inverted	
	RRR (95% CI)	p value	RRR (95% CI)	p value
Dysfunctional swallowing	1	<0.001	1	0.343
No ^a	5.85		3.24	
Si	(2.23–15.36)		(0.28–36.88)	
Oral respiration	1	0.101	1	0.734
No ^a	1.01		1.37	
Si	(0.89–3.68)		(0.21–8.66)	

^a reference category

RRR: Relative risk ratio corrected for age and sex

removable appliances aimed at modifying low tongue posture [19].

A second meta-analysis conducted in 2018 by Fragas and coworkers also associated mouth breathing with an increased risk of malocclusions, in agreement with our findings [23].

Our study also revealed data that contradict some well-established findings in the literature. The first discrepancy concerns the lack of evidence in our study supporting the protective role of breastfeeding against malocclusions (particularly Angle's Class II) when such oral habits are practiced in the first 6–12 months of life, as reported in the systematic review by Abate [1]. The protective role of breastfeeding is based on its ability to promote favorable dynamics for proper maxillary development, such as proper lip seal, mandibular function, correct tongue position against the palate, and normal nasal breathing in newborns [1, 16]. Furthermore, early breastfeeding reduces (or eliminates) the need for artificial feeding with a bottle, which is associated with an increased risk of malocclusion [1, 29].

However, our study revealed that breastfeeding does not always reduce bottle feeding; the two oral habits may coexist. This coexistence (one protective and one promoting malocclusions) observed in our study population may explain why our analysis did not detect a protective effect of breastfeeding.

A second discrepancy with the literature is the lack of correlation in our findings between malocclusions and nonnutritive sucking habits (NNSH), such as pacifier use, finger sucking, and pencil chewing. A recent systematic review revealed that the presence and duration of NNSHs increase the risk of developing malocclusions. A possible explanation for our lack of correlation may be that certain types of malocclusions more often associated with NNSHs (e.g., open bite) may regress if these habits are stopped by age four (or even later), with a regression rate between 50% and 100% [2]. Our Analysis, therefore, conducted in children aged 6–12 years, may have included

children in whom these conditions were present in the past but had already resolved by the time of examination.

Notably, some (although fewer) cross-sectional studies also reported no correlation between NNSHs and malocclusions, suggesting that other factors related to maxillary development may mask or modulate this relationship and that multifactorial and environmental components may be involved (Santos T.T. et al., 2018).

Finally, the data collected in our study suggest that not only the type but also the number of oral habits present in each child could influence the risk of malocclusion. Data analysis revealed a rising trend: patients with a very low number of habits (0–1) presented a malocclusion prevalence of 31.6%, whereas in those with 2–3 habits, the percentage increased significantly to 74.7%. In cases where more than three harmful habits were identified, the prevalence of malocclusion reached 84%. These findings suggest a proportional relationship between the number of dysfunctional oral behaviors and the onset of occlusal alterations. The simultaneous presence of multiple incorrect habits appears to amplify the negative effect on occlusal development, likely due to prolonged and combined interference with the physiological processes of craniofacial and dentoalveolar growth.

Thus, assessing the total number of oral habits, rather than evaluating each habit in isolation, may offer a more accurate method for identifying children at high risk for malocclusion. This approach could facilitate earlier intervention and more targeted preventive strategies.

Limitations of the study

While this study offers important insight into the relationship between oral habits and malocclusion in children, several limitations should be acknowledged when the findings are interpreted.

First, the study was conducted in a single clinical setting, specifically, the Pediatric Dental Clinic at the University of Perugia. As a result, the sample consisted exclusively of children who were already undergoing dental evaluations or treatments. This could introduce selection bias, as children referred to or accessing a university dental clinic might not be representative of the general pediatric population. Furthermore, as the study is retrospective, and not prospective, it makes the relationship between malocclusions and oral habits less strong in terms of association. Therefore, while the results are meaningful for the context in which they were gathered, they should be interpreted with caution when generalizing to all Italian children or broader population and the lack of data regarding longitudinal follow-up did not allow us to assess how oral habits may change over time and how such changes may influence the development or resolution of malocclusions. In addition, it is important to consider the possibility of recall bias, given that

Table 7 Descriptive analysis of sample characteristics, stratified by overbite (Normal, increased and Inverted)

Variables	Total N= 190	Overbite			p value
		Normal n (%)	Open n (%)	Closed n (%)	
Age (Years), mean ± SD	8.58 ± 2.05	8.54 ± 2.09	8.48 ± 2.08	8.69 ± 1.99	0.843*
Sex, n (%)					0.751**
Male	96 (50.53)	47 (47.96)	15 (51.72)	34 (53.98)	
Female	94 (49.47)	51 (52.04)	14 (48.28)	29 (46.03)	
Breastfeeding, n (%)					0.749**
No	49 (25.79)	23 (23.47)	8 (27.59)	18 (28.57)	
Yes	141 (74.21)	75 (76.53)	21 (72.41)	45 (71.43)	
Feeding bottle, n (%)					0.961**
No	75 (39.68)	38 (38.78)	12 (41.38)	25 (40.32)	
Yes	114 (60.32)	60 (61.22)	17 (58.52)	37 (59.68)	
Pacifier, n (%)					0.519**
No	99 (52.11)	55 (56.12)	14 (48.28)	30 (47.62)	
Yes	91 (47.89)	43 (43.88)	15 (51.72)	33 (52.38)	
Finger, n (%)					0.482**
No	157 (82.63)	79 (80.61)	23 (79.31)	55 (87.30)	
Yes	33 (17.37)	19 (19.39)	6 (20.69)	8 (12.70)	
Onychophagy, n (%)					0.237**
No	164 (86.32)	81 (82.65)	25 (86.21)	58 (92.06)	
Yes	26 (13.68)	17 (17.35)	4 (13.79)	5 (7.94)	
Lapisphagia, n (%)					0.167**
No	173 (91.05)	87 (88.78)	29 (100.00)	57 (90.48)	
Yes	17 (8.95)	11 (11.22)	0 (0.00)	6 (9.52)	
Dysfunctional swallowing, n (%)					0.003***
No	50 (26.32)	34 (34.69)	1 (3.45)	15 (23.81)	
Yes	140 (73.68)	64 (65.31)	28 (96.55)	48 (76.19)	
Oral respiration, n (%)					0.026**
No	103 (55.98)	60 (62.50)	9 (33.33)	34 (55.74)	
Yes	81 (44.02)	36 (37.50)	18 (66.67)	27 (44.26)	
Short phrenulum, n (%)					0.100**
No	156 (82.11)	77 (78.57)	22 (75.86)	57 (90.48)	
Yes	34 (17.89)	21 (21.43)	7 (24.14)	6 (9.52)	
Analisi post hoc					
	Normal vs. Open	Normal vs. Closed	Open vs. Closed		
Dysfunctional swallowing	0.001	0.143	0.017		
Oral respiration	0.007	0.399	0.052		

SD: Standard deviation; *F: Kruskal-wallis; ** Fisher's test; *** χ^2 testPost hoc: χ^2 test correct by Bonferroni, $p < 0.0125$

some information regarding children's oral habits was collected through statements provided by parents during the anamnestic interview. Parents may not always be able to accurately remember or correctly report the frequency and duration of past habits, which could lead to classification errors or an underestimation of certain behaviours. This limitation is typical of retrospective cross-sectional studies based on self-reported data and should be taken into account when assessing the strength of the associations observed.

Conclusion

In conclusion, this study highlights a strong and clinically relevant association between specific oral habits and malocclusions in children aged 6–12 years. Among all the habits examined, dysfunctional swallowing and mouth breathing were the most significant predictors of malocclusion. Our findings revealed that children with these habits were more likely to develop not only general malocclusions but also specific conditions, such as Class II and III dental classes, increased overjet, and open bite. These results reinforce the need for early identification and management of orofacial dysfunctions

Table 8 Estimated relative risk ratios of presenting overbite open or closed by multinomial logistic regression

	Overbite			
	Open		Closed	
	RRR (95% CI)	p value	RRR (95% CI)	p value
Dysfunctional swallowing	1	0.028	1	0.236
No ^a	10.82		1.65	
Si	(1.28–90.97)		(0.72–3.79)	
Oral respiration	1	0.285	1	0.920
No ^a	1.69		1.04	
Si	(0.64–4.46)		(0.49–2.20)	

^a reference category

RRR: Relative risk ratio corrected for age and sex

Table 9. Distribution of malocclusions based on the number of oral habits

N. Oral Habits	Total	Malocclusion		P value
		Present n (%)	Absent n (%)	
0–1	19	6 (31.58)	13 (68.42)	<0.001
2–3	71	53 (74.65)	18 (25.35)	
>3	100	84 (84.00)	16 (16)	

χ² test

during growth. An especially noteworthy outcome of this research is the observed cumulative effect of multiple habits: the risk of malocclusion increased substantially with the number of coexisting dysfunctional oral behaviors. This suggests that a broader, more integrated approach, one that considers not only the presence of a single habit but also the overall behavioral pattern, is crucial for identifying children at greater risk. Given these insights, encouraging early screening for dysfunctional oral habits in pediatric populations may help clinicians intervene promptly and reduce the likelihood of developing more severe malocclusions over time.

Abbreviations

OR	Odds Ratio
CI	Confidence Interval
RRR	Relative risk ratio
SD	Standard deviation
p	p value

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12903-025-06892-5>.

Supplementary material 1

Acknowledgements

We would like to thank all participants for their contribution.

Authors' contributions

S.C. and F.V. designed the study. A.V. reported medical records, wrote the manuscript and was the corresponding author. G.L. and M.S. wrote the paper. C.T.T. reported medical records, wrote and reviewed the manuscript. L.B. and

R.C. helped in the development of the study. A.M. and D.C. analyzed and interpreted the data.

The authors declare no funding declaration.

Data availability

No datasets were generated or analysed during the current study.

Declarations**Ethical approval and consent to participate**

For the study was obtained from the CER Umbria-Regional Ethics Committee of Umbria (CE-1501/24). Informed consent was obtained from all subjects and/or their legal guardian(s).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Section of Odontostomatologic Surgery, University of Perugia, Perugia 06126, Italy

²Department of Life, Health and Environmental Sciences, University of L'Aquila, L'Aquila 67100, Italy

³DDS - private practice, 05100 Terni, Italy/Italy

Received: 16 May 2025 / Accepted: 2 September 2025

Published online: 06 October 2025

References

- Abate A, Cavagnetto D, Fama A, Maspero C, Farronato G. Relationship between breastfeeding and malocclusion: a systematic review of the literature. *Nutrients*. 2020;12(12):3688. <https://doi.org/10.3390/nu12123688>. (PMID: 33265907; PMCID: PMC7761290).
- Adriano LZ, Derech CD, Massignan C, Flores-Mir C, Porporatti AL, Canto GL, Bolan M. Anterior open bite self-correction after cessation of nonnutritive sucking habits: a systematic review. *Eur J Orthod*. 2023;45(3):235–243. <https://doi.org/10.1093/ejo/cjac054>. PMID: 37080715.
- Alhammedi MS, Halboub E, Fayed MS, Labib A, El-Saaidi C. Global distribution of malocclusion traits: A systematic review. *Dental Press J Orthod*. 2018 Nov-Dec;23(6):40.e1-40.e10. <https://doi.org/10.1590/2177-6709.23.6.40.e1-10.onl>. Erratum in: *Dental Press J Orthod*. 2019;24(3):113. doi: 10.1590/2177-6709.24.3.113.err. PMID: 30672991; PMCID: PMC6340198.
- American Academy of Pediatric Dentistry. Policy on pacifiers. The reference manual of pediatric dentistry. Chicago, Ill.: American Academy of Pediatric Dentistry; 2024. pp. 79–82.
- Amro H, Najjar S, Owda M, Elayyan F. A comprehensive national survey on malocclusion prevalence among Palestinian children. *BMC Oral Health*. 2024;24(1):664. <https://doi.org/10.1186/s12903-024-04432-1>. (PMID: 38849789; PMCID: PMC11157726).
- Anand T, Garg AK, Singh S. Effect of socioeconomic, nutritional status, diet, and oral habits on the prevalence of different types of malocclusion in school-children. *Acta Biomed*. 2022;93(3):e2022161. <https://doi.org/10.23750/abm.v93i3.13027>.
- Akbari M, Lankarani KB, Honarvar B, Tabrizi R, Mirhadi H, Moosazadeh M. Prevalence of malocclusion among Iranian children: a systematic review and meta-analysis. *Dent Res J (Isfahan)*. 2016;13(5):387–95. <https://doi.org/10.4103/1735-3327.192269>.
- Barca L, Mazzuca C, Borghi AM. Pacifier overuse and conceptual relations of abstract and emotional concepts. *Front Psychol*. 2017;8:2014. <https://doi.org/10.3389/fpsyg.2017.02014>.
- Belitz GS, Furlan LNJ, Knorst JK, Berwig LC, Ardenghi TM, Ferrazzo VA, et al. Association between malocclusion in the mixed dentition with breastfeeding and past nonnutritive sucking habits in school-age children. *Angle Orthod*. 2022;92(5):669–76. <https://doi.org/10.2319/111821-848.1>.
- Blank R, Barnett AL, Cairney J, Green D, Kirby A, Polatajko H, Rosenblum S, Smits-Engelsman B, Sugden D, Wilson P, Vinçon S. International clinical practice recommendations on the definition, diagnosis, assessment, intervention,

- and psychosocial aspects of developmental coordination disorder. *Dev Med Child Neurol.* 2019;61(3):242–85. Epub 2019 Jan 22. PMID: 30671947; PMCID: PMC6850610.
11. Boronat-Catalá M, Bellot-Arcís C, Montiel-Company JM, Almerich-Silla JM, Catalá-Pizarro M. Does breastfeeding have a long-term positive effect on dental occlusion? *J Clin Exp Dent.* 2019;11(10):e947–51. <https://doi.org/10.4317/jced.56312>. PMID: 31636865; PMCID: PMC6797467.
 12. Borrie FR, Bearn DR, Innes NP, Iheozor-Ejiogor Z. Interventions for the cessation of nonnutritive sucking habits in children. *Cochrane Database Syst Rev.* 2015;2015(3):CD008694. <https://doi.org/10.1002/14651858.CD008694.pub2>. PMID: 25825863; PMCID: PMC8482062.
 13. Botero-Mariaca O, Sierra-Alzate V, Rueda ZV, Gonzalez D. Tongue function in children with anterior open bite: a case-control study. *Int Orthod.* 2018;16(4):733–43.
 14. British Orthodontic Society. Advice sheet. Nonnutritive sucking habits (NNSH). 2023. <https://bos.org.uk/wp-content/uploads/2024/12/NON-NUTRITIVE-SUCKING-HABITS-NNSH-2024.pdf>
 15. Campbell S, Goldstein G. Angle's classification—a prosthodontic consideration: best evidence consensus statement. *J Prosthodont.* 2021;30(51):67–71. <https://doi.org/10.1111/jopr.13307>.
 16. Cenzato N, Berti C, Cazzaniga F, Di lasio G, Scolaro A, Maspero C. Influence of the type of breastfeeding as a risk or protective factor for the onset of malocclusions: a systematic review. *Eur J Paediatr Dent.* 2023;24(4):329–333. doi: 10.23804/ejpd.2023.2015. PMID: 38015113.
 17. Chen H, Lin L, Chen J, Huang F. Prevalence of malocclusion traits in primary dentition, 2010–2024: a systematic review. *Healthcare.* 2024;12(13):1321. <https://doi.org/10.3390/healthcare12131321>.
 18. Costa CTD, Shqair AQ, Azevedo MS, Goettems ML, Bonow MLM, Romano AR. Pacifier use modifies the association between breastfeeding and malocclusion: a cross-sectional study. *Braz Oral Res.* 2018;32(0):e101. <https://doi.org/10.1590/1807-3107bor-2018.vol32.0101>.
 19. Dehesa-Santos A, Iber-Díaz P, Iglesias-Linares A. Genetic factors contributing to skeletal class III malocclusion: a systematic review and meta-analysis. *Clin Oral Investig.* 2021;25(4):1587–612. <https://doi.org/10.1007/s00784-020-03731-5>.
 20. De Ridder L, Aleksieva A, Willems G, Declerck D, Cadenas de Llano-Pérua M. Prevalence of orthodontic malocclusions in healthy children and adolescents: A systematic review. *Int J Environ Res Public Health.* 2022;19(12):7446. <https://doi.org/10.3390/ijerph19127446>. PMID: 35742703; PMCID: PMC9223594.
 21. Dos Santos RR, Nayme JG, Garbin AJ, Saliba N, Garbin CA, Moimaz SA. Prevalence of malocclusion and related oral habits in 5- to 6-year-old children. *Oral Health Prev Dent.* 2012;10(4):311–8. PMID: 23301231.
 22. Fraga WS, Seixas VM, Santos JC, Paranhos LR, César CP. Mouth breathing in children and its impact in dental malocclusion: a systematic review of observational studies. *Minerva Stomatol.* 2018;67(3):129–38. <https://doi.org/10.23736/S0026-4970.18.04015-3>.
 23. Giugliano D, Apuzzo F, Jamilian A, Perillo L. Relationship between malocclusion and oral habits. *Curr Res Dent.* 2015;5(2):17–21. <https://doi.org/10.3844/crdsp.2014.17.21>.
 24. Gonzalez P, Martinez MB, Sierra V, Rueda ZV, Botero-Mariaca P. Assessment of tongue position during oral phase swallowing in children with anterior open bite and normal vertical bite. *J Indian Soc Pedod Prev Dent April-June.* 2019;37(2):167–71.
 25. Ghodasra R, Brizuela M. *Orthodontics, Malocclusion.* 2023 Apr 23. In: StatPearls, Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 37276298.
 26. Grippaudo C, Paolantonio EG, Antonini R, Saule G, La Torre R, Deli. Association between oral habits, mouth breathing, and malocclusion. *Acta Otorhinolaryngol Ital.* 2016;36:386–94.
 27. Gómez-González C, González-Mosquera A, Alkhraisat MH, Anitua E. Mouth breathing and its impact on atypical swallowing: a systematic review and meta-analysis. *Dent J Basel.* 2024;12(2):21. <https://doi.org/10.3390/dj12020021>.
 28. Hermont AP, Martins CC, Zina LG, Auad SM, Paiva SM, Pordeus IA. Breastfeeding, bottle feeding practices and malocclusion in the primary dentition: a systematic review of cohort studies. *Int J Environ Res Public Health.* 2015;12(3):3133–51. <https://doi.org/10.3390/ijerph120303133>.
 29. Jaiswal S, Sayed F, Kulkarni VV, Kulkarni P, Tekale P, Fafat K. Comparative evaluation of the relationship between airway inadequacy, head posture, and craniofacial morphology in mouth-breathing and nasal-breathing patients: a cephalometric observational study. *Cureus.* 2023;15(10):e47435. <https://doi.org/10.7759/cureus.47435>. (PMID: 38022105; PMCID: PMC10663097).
 30. Jiménez JJ. Importance of atypical swallowing in malocclusions. *Sanmarquina Dent.* 2016;19(2):41–4. <https://doi.org/10.15381/os.v19i2.12917>.
 31. Josell SD. Habits affecting dental and maxillofacial growth and development. *Dent Clin North Am.* 1995;39(4):851–60. PMID: 8522046.
 32. Karjalainen S, Rönning O, Lapinleimu H, Simell O. Association between early weaning, nonnutritive sucking habits and occlusal anomalies in 3-year-old Finnish children. *Int J Paediatr Dent.* 1999;9(3):169–73. <https://doi.org/10.1046/j.1365-263x.1999.00133.x>.
 33. Katib HS, Aljashash AA, Albishri AF, Alfaihi AH, Alduhayan SF, Alotaibi MM, Otaif TS, Bashikh RA, Almadani JA, Thabet AM, Alaman KA. Influence of oral habits on pediatric malocclusion: etiology and preventive approaches. *Cureus.* 2024;16(11):e72995. <https://doi.org/10.7759/cureus.72995>. PMID: 39640127; PMCID: PMC11617490.
 34. Lawlor CM, Choi S. Diagnosis and management of pediatric dysphagia: a review. *JAMA Otolaryngol Head Neck Surg.* 2020;146(2):183–91. <https://doi.org/10.1001/jamaoto.2019.3622>.
 35. Le Révérend BJD, Edelson LR, Loret C. Anatomical, functional, physiological and behavioral aspects of the development of mastication in early childhood. *Br J Nutr.* 2014;111(3):403–14. <https://doi.org/10.1017/S0007114513002699>.
 36. Ling HTB, Sum FHKMH, Zhang L, Yeung CPW, Li KY, Wong HM, et al. Association between nutritive and nonnutritive sucking habits and primary dental occlusion. *BMC Oral Health.* 2018;18:145.
 37. Lombardo G, Vena F, Negri P, Pagano S, Barilotti C, Paglia L, et al. Worldwide prevalence of malocclusion in different dentition stages: a systematic review and meta-analysis. *Eur J Paediatr Dent.* 2020;21(2):115–22.
 38. Markkanen S, Niemi P, Rautiainen M, Saarenmaa-Heikkilä O, Himanen SL, Sato-maa AL, et al. Craniofacial and occlusal development in 2.5-year-old children with obstructive sleep apnoea syndrome. *Eur J Orthod.* 2019;41:316–21. <https://doi.org/10.1093/ejo/cjz009>.
 39. Makaremi M, Zink K, de Brondeau F. The importance of elevated masticatory forces on the stability of maxillary expansion. *J Dentofac Anom Orthod.* 2015;18:203. <https://doi.org/10.1051/odfen/2018100>.
 40. Maspero C, Prevedello C, Giannini L, Galbiati G, Farronato G. Atypical swallowing: a review. *Minerva Stomatol.* 2014;63(6):217–27. English, Italian. PMID: 25267151.
 41. Moimaz SAS, Zina LG, Rocha NB, Saliba NA, Saliba O. Nonnutritive sucking habits: prevalence and associated factors in Brazilian children. *Brazilian Oral Res.* 2008;22(4):343–8. <https://doi.org/10.1590/S1806-83242008000400006>.
 42. Mozzanica F, Pizzorni N, Scarponi L, Crimi G, Schindler A. Impact of oral myofunctional therapy on orofacial myofunctional status and tongue strength in patients with tongue thrust. *Folia Phoniatr Logop.* 2021;73(5):413–21. Epub 2020 Oct 28. PMID: 33113529.
 43. Paglia L. Interceptive orthodontics: awareness and prevention is the first cure. *Eur J Paediatr Dent.* 2023;24(1):5–5. <https://doi.org/10.23804/ejpd.2023.24.01.01>.
 44. Peres KG, Cascaes AM, Peres MA, Demarco FF, Santos IS, Matijasevich A, Barros A.J.D. Exclusive breastfeeding and risk of dental malocclusion. *Pediatrics.* 2015;136:e60–7. <https://doi.org/10.1542/peds.2014-3276>.
 45. Rodríguez-Olivos LHG, Chacón-Uscamaita PR, Quinto-Argote AG, Puma-hualcca G, Pérez-Vargas LF. Deleterious oral habits related to vertical, transverse and sagittal dental malocclusion in pediatric patients. *BMC Oral Health.* 2022;22(1):88. <https://doi.org/10.1186/s12903-022-02122-4>. PMID: 35321719; PMCID: PMC8944101.
 46. Róžańska-Perlińska D, Jaszczur-Nowicki J, Kruczkowski D, Bukowska JM. Dental malocclusion in mixed dentition children and its relation to podal system and gait parameters. *Int J Environ Res Public Health.* 2023;20(3):2716. <https://doi.org/10.3390/ijerph20032716>.
 47. Sadoun C, Templier L, Alloul L, Rossi C, Renouales ID, Sanchez IN, Sahagún PM. Effects of nonnutritive sucking habits on malocclusions: a systematic review. *J Clin Pediatr Dent.* 2024;48(2):4–18. <https://doi.org/10.22514/jocpd.2024.029>. Epub 2024 Mar 3. PMID: 38548628.
 48. Shetty SR, Munshi AK. Oral habits in children—a prevalence study. *J Indian Soc Pedod Prev Dent.* 1998;16(2):61–6. PMID: 11813757.
 49. Sum FHKMH, Zhang L, Ling HTB, Yeung CPW, Li KY, Wong HM, Yang Y. Association of breastfeeding and three-dimensional dental arch relationships in primary dentition. *BMC Oral Health.* 2015;15:30. <https://doi.org/10.1186/s12903-015-0010-1>.
 50. Tang H, Liu Q, Lin JH, Zeng H. Three-dimensional morphological analysis of the palate of mouth-breathing children in mixed dentition. *Hua Xi Kou Qiang Yi Xue Za Zhi.* (2019) 37:389–93. <https://doi.org/10.7518/hxkq.2019.04.009> [DOI] [PMC free article] [PubMed] [Google Scholar].

52. Thomaz EBAF, Alves CMC, Gomes E, Silva LF, Ribeiro de Almeida CCC, Soares de Britto E, Alves MTS, Hilgert JB, Wendland EM. Breastfeeding versus bottle feeding on malocclusion in children: A Meta-Analysis study. *J Hum Lact.* 2018;34(4):768–88. Epub 2018 Mar 29. PMID: 29596751.
53. Ugolini A, Agostino P, Silvestrini-Biavati A, Harrison JE, Batista KB. Orthodontic treatment for posterior crossbites. *Cochrane Database Syst Rev.* 2021;(12):CD000979. <https://doi.org/10.1002/14651858.CD000979.pub3>.
54. Vázquez-Nava F, Quezada-Castillo JA, Oviedo-Treviño S, et al. Association between allergic rhinitis, bottle feeding, nonnutritive sucking habits, and primary dentition malocclusion. *Arch Dis Child.* 2006;91(10):836–40.
55. Vena F, D'Amico G, Cardarelli F, Cianetti S, Severino M. Interceptive orthodontic treatment with elastodontic appliance for open bite in early childhood: a case series. *Oral Implantology.* 15(1), 25–8.
56. Viggiano D, Fasano D, Monaco G, Strohmer L. Breast feeding, bottle feeding, and nonnutritive sucking; effects on occlusion in deciduous dentition. *Arch Dis Child.* 2004;89(12):1121–3. <https://doi.org/10.1136/adc.2003.029728>. PMID: 15557045; PMCID: PMC1719762.
57. Villa MP, Brasili L, Ferretti A, Vitelli O, Rabasco J, Mazzotta AR, Pietropaoli N, Martella S. Oropharyngeal exercises to reduce symptoms of OSA after AT. *Sleep Breath.* 2015;19(1):281–9. <https://doi.org/10.1007/s11325-014-1011-z>. Epub 2014 May 26. PMID: 24859614.
58. Viswanathan S, Jadcherla S. Feeding and swallowing difficulties in neonates: developmental physiology and pathophysiology. *Clin Perinatol.* 2020;47(2):223–41. <https://doi.org/10.1016/j.clp.2020.02.005>. Epub 2020 Feb 19. PMID: 32439109.
59. Warren J, Slayton L, Yonesu T, et al. Effects of nonnutritive sucking habits on occlusal characteristics in mixed dentition. *Pediatr Dent.* 2005;27:445–50.
60. Watted N, Lone IM, Zohud O, Midlej K, Proff P, Iraqi FA. Comprehensive Deciphering the complexity of the deep bite: insight from animal model to human subjects. *J Pers Med.* 2023;13(10):1472. <https://doi.org/10.3390/jpm13101472>. PMID: 37888083; PMCID: PMC10608509.
61. Yamashita H, Yotsuya K, Takeuchi T, Oda S, Hara A, Sekiguchi H, Yakushiji M. Awareness of malalignment and malocclusion in children and their guardians. *Bull Tokyo Dent Coll.* 2008;49(1):7–13.
62. Zhang Z. Model building strategy for logistic regression: purposeful selection. *Ann Transl Med.* 2016. <https://doi.org/10.21037/atm.2016.02.15>.
63. Zhou C, Duan P, He H, Song J, Hu M, Liu Y, Liu Y, Guo J, Jin F, Cao Y, Jiang L, Ye Q, Zhu M, Jiang B, Ruan W, Yuan X, Li H, Zou R, Tian Y, Gao L, Shu R, Chen J, Liu R, Zou S, Li X. Expert consensus on pediatric orthodontic therapies of malocclusions in children. *Int J Oral Sci.* 2024;16(1):32. <https://doi.org/10.1038/s41368-024-00299-8>. PMID: 38627388; PMCID: PMC11021504.
64. Chiba FY, Chiba EK, Moimaz SAS, Matsushita DH, Garbin AJJ, Garbin CAS. Malocclusion and its relationship with oral health-related quality of life in patients with eating disorders. *Dental Press J Orthod.* 2022 Jun 10;27(2):e2220305. doi: 10.1590/2177-6709.27.2.e2220305.oar. PMID: 35703616; PMCID: PMC9191855.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.