

Effects of conventional and orthodontic pacifiers on the dental occlusion of children aged 24–36 months old

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Aim. To investigate the effects of conventional and orthodontic pacifiers on the prevalence of malocclusion (MO) considering frequency, duration, and intensity of the sucking habit.

Design. Data were collected at three time-points: birth, T1; (12–24 months old), T2; (24–36 months old), T3 and were divided into three groups: control (GC; 110), without non-nutritive sucking habits; orthodontic pacifiers (GOrth; 55); conventional pacifiers (GConv; 55). A questionnaire was applied. Clinical examination was performed at T3. The groups were compared as to the prevalence and severity of anterior open bite (AOB),

accentuated overjet, anterior crossbite, posterior crossbite (PCB).

Results. The use of pacifiers was associated with occurrence of MO compared to GC ($P < 0.05$). Frequency, intensity, and duration of pacifier use was also associated with MO. There was significant difference in the prevalence of MO between GConv and GOrth for AOB ($P = 0.027$). Only GConv exhibited higher odds of PCB compared to GC ($P = 0.040$). The prevalence of MO was significantly higher in pacifiers users ($P < 0.001$).

Conclusion. The prevalence of MO was higher among children who used pacifiers. According to a general trend, the use of conventional pacifiers was associated to severe anterior open bite and overjet.

Introduction

Finger sucking and pacifiers are non-nutritive sucking habits (NNSHs) that induce changes in muscle contraction patterns, which might have deleterious effects on dentition and the face. Some evidence indicates that NNSHs lead to the occurrence of anterior open bite (AOB)^{1,2}, anterior overjet (AO), Angle's Class II malocclusion^{3–7}, posterior crossbite (PCB)^{1,4,8}, and enamel alteration.⁹ These abnormalities might alter breathing, mastication, deglutition, and phonation^{10–12}.

The prevalence of NNSHs among children varies from 17% to 90%, as a function of both age range and the population under study^{5,11,13,14}. The use of pacifiers is the most prevalent NNSH, as the behaviour is socially accepted and widely spread¹⁴. Pacifiers are mainly used to make children stop crying, help them fall asleep and satisfy their need for sucking^{14,15}.

Two models of pacifiers, namely, conventional and orthodontic, are commercially available. The indication of orthodontic pacifiers is grounded on the anatomical design of the nipple, allegedly similar to the shape the maternal nipple acquires during breastfeeding, and of the guard, which is assumed to promote an adequate lip seal^{2,6,8,16}. It is believed that the use of such pacifiers

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induces patterns of muscle contraction, tongue position and nasal breathing similar to the ones occurring during breastfeeding, whereby they would not interfere with the growth and development of the face and occlusion².

Nevertheless, there is no consensus on whether orthodontic pacifiers are truly less deleterious for occlusion compared to conventional ones^{2,6,8,16}. Adair *et al.*² compared the effects of conventional and orthodontic pacifiers on children aged 24–59 months old and found larger AO among the users of orthodontic pacifiers and greater frequency of AOB among the users of conventional pacifiers, but the differences were not significant. Adair *et al.*⁶ then investigated the effects of past and ongoing use of pacifiers and concluded that orthodontic pacifiers did not seem to have any advantage over conventional pacifiers.

Other authors^{8,16} also compared the abnormalities of the primary dentition caused by conventional and orthodontic pacifiers. Independently from the model used, pacifiers were associated with AOB, PCB, and AO. Yet, the prevalence and severity of such alterations are lower with orthodontic compared to conventional pacifiers¹⁶.

The studies that compared orthodontic versus conventional pacifiers were cross-sectional in design and did not adjust the analyses for eventual confounders^{2,6,8,16}. In addition, no such studies considered the frequency, intensity, and duration of the sucking habit simultaneously. Some studies had small samples^{2,8,16} that were recruited from dental clinics, which might have led to selection bias^{2,6}.

Thus, as a function of the controversial results and methodological limitations of the available studies on the subject of interest, the aim of the present study was to investigate the effects of conventional and orthodontic pacifiers on the prevalence and severity of MO in the primary dentition in a birth cohort from the Northeastern Brazilian region, taking the duration, frequency, and intensity of the sucking habit into consideration.

Materials and methods

The BRISA (*Brazilian Birth Cohort Studies, Ribeirão Preto-São Luís*)¹⁷ involves a birth cohort corresponding to two Brazilian towns with opposite socioeconomic conditions – São Luís (Maranhão) and Ribeirão Preto (São Paulo). In the present study, only the data relative to the São Luís sample were used. The study was approved by the research ethics committee of the University Hospital, Federal University of Maranhão – ruling no. 072/11. Only children whose parents signed an informed consent form were included in the study.

Data collection was performed at three time-points. The baseline (T1) corresponded to the children's birth, on which occasion data were collected on the family socioeconomic status and pre-natal and birth characteristics. The second assessment (T2) was performed at age 12–24 months old, when children were recruited to collect data on NNSHs by means of a questionnaire applied to their mothers/caregivers. On that occasion, the children were divided in three groups: non-exposed or control (GC), namely, children who had never used pacifiers; children who used conventional pacifiers (GConv); and children who used orthodontic pacifiers (GOrth). The children were then asked to come back 1 year later (T3), namely, at age 24–36 months old, when they were subjected to clinical examination of occlusion and were administered a questionnaire investigating the frequency, intensity and duration of NNSHs.

The initial cohort sample consisted of 5067 non-twin live-birth babies recruited by means of stratified probabilistic sampling through systematic application of the lottery method encompassing all of the public and private maternity hospitals in São Luís County¹⁷. A total of 1,152 infants were considered eligible at the T2 assessment: age 12–24 months old, without enlarged adenoids or respiratory problems, without history of finger sucking, lip sucking, lip biting or lingual interposition, without history of use of orthodontic appliances and without history of oral and maxillofacial surgery.

It was estimated that a sample of 200 participants had 90% power to detect a difference of 25% in the prevalence of MO between users and non-users of pacifiers, with a type I error of 5%, a 1 : 2 ratio between exposed and non-exposed children and an expected frequency of MO among the non-exposed children of 40%. The sample size was increased by 10% to compensate for eventual losses. As a result, the final, simple and random sample consisted of 220 children from both genders selected by means of the lottery method without replacements and was stratified into 110 children in GC, 55 in GConv and 55 in GOrth.

Data collection was performed by two previously trained investigators (A.A.S.J.L.; K.B.). Orthodontic examination was performed with the examiners blinded as to the children's history of NNSHs. Clinical examination was performed first, and then the children's mothers were interviewed. Children with rampant caries, large dental fractures, and without eruption of all of the primary first molars and children who used both models of pacifiers according to the mothers' report were excluded from the study.

The dependent variable was presence of MO. The following occlusal parameters were recorded: (1) erupted primary teeth; (2) terminal plane of the primary first or second molars, categorized following Baume¹⁸ as flush terminal plane, distal step or mesial step; (3) deep overbite (DOB) assessed based on the measurement of the vertical distance between the incisal margins of the maxillary and mandibular central incisors as described by Warren *et al.*¹; DOB was categorized as absent (presence of AOB, anterior end-to-end bite, overbite up to 2 mm) or present (more than 2 mm); (4) accentuated overjet (AO), namely, the horizontal distance from the vestibular side of the mandibular central incisor and the palatal side of the most anterior maxillary incisor¹; AO was categorized as absent (up to 2 mm) or present (more than 2 mm); (5) AOB, defined as the vertical distance between the incisal margins of the maxillary and mandibular central incisors¹; AOB was categorized as absent (presence of DOB or anterior end-to-end bite) or present;

(6) PCB, categorized as absent (normal transverse relationship between the maxillary and mandibular posterior teeth) or present (one or more maxillary posterior teeth abnormally for palatal relative to the antagonist; unilaterally or bilaterally)^{2,6,8,16}.

Malocclusion was also classified as (1) MO on the horizontal plane, categorized as normal, AO or anterior crossbite (ACB); (2) MO on the vertical plane, categorized as normal, DOB or AOB; and (3) MO in the transverse plane, categorized as normal, accentuated overjet or PCB.

Oral examination consisted of visual inspection; it was performed at a dental office, under artificial light, using spatulas, mouth mirrors, probes calibrated in millimeters (Hufriedy© 2014 Mfg. Co, LLC) and disposable protective materials. All measurements were performed directly in the mouth.

The independent variable was pacifier-sucking habit, categorized as the following: GC, the child never used pacifiers; GConv, use of conventional pacifiers only; or GOrth, use of orthodontic pacifiers only. To reduce the odds of measurement bias in the classification of pacifiers, the parents/caregivers were requested to bring the pacifiers to the assessment appointments, and whenever they did not, they were shown a set of samples to indicate the ones the children used.

In addition, the frequency, intensity, and duration of the pacifier sucking habit (Graber's triad) were assessed. The frequency was calculated per period of use (daytime and/or nighttime). To define the sucking intensity, the parents/caregivers were asked whether the children contracted the muscles (made faces) or made noises while sucking the pacifier. Duration was calculated by subtracting the age of onset from the age at which use was stopped.

The data were analysed using Stata software (Stata Corp. College Station, TX, USA), version 11.0. The normality of the distribution of numerical variables was investigated by means of the Shapiro-Wilk test. Analysis of variance (ANOVA) followed by Tukey's post hoc test was used to compare means of numerical variables between groups. The categorical variables were summarized as

absolute and relative frequencies and were analysed by way of the chi-square or Fisher's exact test. The correlation between MO measurements (in millimeters) and numerical variables was assessed by means of Pearson's correlation coefficient.

To assess the effects of the two types of pacifiers on the occurrence of MO, odds ratios (ORs) and corresponding 95% confidence intervals (95% CIs) were calculated in logistic regression analyses when the outcomes were dichotomous and by means of multinomial regression when outcomes included more than two categories. Multivariate analyses were performed to adjust for confounding factors; for that purpose, the variables with *P*-values under 0.20 on univariate analysis were selected. The significance level was set to 0.05% in all analyses.

Results

Among 1152 eligible children, 695 (60.33%) did not use pacifiers at T3, while 457 (39.67%) did. Among the latter, 270 (59.08%) used conventional pacifiers and 187 (40.92%) orthodontic pacifiers. A total of 274 children were subjected to examination; 54 were excluded because they had a finger sucking habit, lip sucking habit, respiratory problems or used both types of pacifiers. Therefore, the final sample consisted of 220 children included at T3. According to the mothers' report, the duration of breastfeeding was 15.3 months (± 10.1), exclusive breastfeeding was 4.1 months (± 2.3), and bottle-feeding was 16.8 months (± 10.2). The sociodemographic characteristics of the children and their families are described in Table 1. The sample mainly consisted of children from families with incomes equivalent to one to three times the minimum wage (50.8%), economic class C (58.1%), not enrolled in governmental income transfer programs (70.2%) or in the Family Health Strategy – FHS (82.9%). Most of the mothers had 12 or more years of formal education (63.7%), brown/mulato skin colour (69%) and lived with a partner (82%). In regard to the children, 50.7% were male, 67.2% brown-skinned, and 59.7% under 30 months old. The average age of the children

Table 1. Sociodemographic characteristics of the study sample. São Luís, MA, Brazil. BRISA.

Family characteristics	<i>n</i>	%
Family income (multiples of minimum wage)*		
≤1	26	14.2
1–3	93	50.8
≥3	64	35.0
Family economic class – ABEP†		
A/B	43	19.8
C	126	58.1
D/E	48	22.1
The family receives governmental allowance		
No	139	70.2
Yes	59	29.8
The family is enrolled in FHS		
No	164	82.8
Yes	34	17.2
Maternal formal education (years)		
≥12	128	63.7
9–11	46	22.9
5–8	24	11.9
0–4	3	1.5
Self-reported maternal skin colour		
White	41	19.0
Black	26	12.0
Brown/Mullato	149	69.0
Mother's marital status		
With partner	178	82.0
Without partner	39	18.0
Children's characteristics	<i>n</i>	%
Gender		
Male	110	50.7
Female	107	49.3
Skin colour		
White	54	27.3
Black	11	5.5
Brown/Mullato	133	67.2
Age (months)		
<30	132	59.7
≥30	89	40.3

FHS, Family Health Strategy.

*At the time the children were born (2010), the minimum wage was USD 288.13.

†Economic class according to the Brazilian Association of Research Companies (Associação Brasileira de Empresas de Pesquisa – ABEP).

at T3 was 29.0 (± 2.0) months old. The average ages of the groups were as follows: GC, 29.8 \pm 1.9 months old; GConv, 28.4 \pm 1.7 months old; and GOrth, 28.2 \pm 1.9 months old; these differences were not significant.

A total of 168 (76.4%) children had MO; the prevalence rates of MO were 39.5% on the horizontal plane 65.4% on the vertical plane, and 39.5% on the transverse plane; these rates were significantly higher

($P < 0.001$) among pacifier users compared to GC. The most prevalent types of MO were AO (41.7%), AOB (41.2%) and PCB (31.7%). The prevalence rates of AO ($P < 0.001$), AOB ($P = 0.001$) and PCB ($P = 0.019$) were higher among pacifier users compared to GC. In turn, the prevalence of DOB was higher in GC ($P < 0.001$). The mesial step of the second molar was the most prevalent terminal plane among the primary molars (78.9%) and was mainly found in GC, while the flush terminal plane and distal step were more prevalent among the pacifier users ($P < 0.001$). The prevalence rates of the various categories of MO did not differ as a function of the type of pacifier used, except for AOB ($P = 0.027$), which was more frequent in GConv (55.7%) compared to GOrth (44.3%) – (Table 2).

Approximately 50.9% of the pacifier users had started with the habit within the first month of life. Approximately 78.2% of the children in GConv and 67.3% of the children in GOrth sucked pacifiers day and night; this difference was not statistically significant ($P = 0.2$). The sucking intensity was similar in both groups ($P = 0.52$) and 81.8% of the children in GConv, and 74.5% of the children in GOrth were described as not making any sucking effort.

On bivariate analysis, use of pacifiers was associated with higher odds of AOB (crude OR = 121.9), AO (crude OR = 3.3) and PCB (crude OR = 8.6) and lower odds of DOB (crude OR = 0.2). Flush terminal plane (crude OR = 6.2) and distal step (crude OR = 10.6) of the primary second molar were more prevalent among pacifier users. All of these associations remained significant following adjustment for age and economic class (Table 3).

Approximately 80.4% of the children in GOrth and 81.5% in GConv exhibited some type of MO versus 71.8% in GC ($P = 0.281$). Table 4 describes unadjusted and adjusted associations between MO and pacifier types compared to GC. Analysis adjusted for children's age and gender, economic class and maternal educational level indicated that orthodontic pacifiers were associated with higher odds of developing moderate (adjusted

OR = 42.8) or severe (adjusted OR = 83.8) AOB, moderate AO (adjusted OR = 3.2) and flush terminal plane of the primary second molar (adjusted OR = 6.6). In turn, the children who used conventional pacifiers exhibited higher odds of developing moderate (adjusted OR = 74.6) or severe (adjusted OR = 356.4) AOB, severe AO (adjusted OR = 28.4), PCB (adjusted OR = 10.7), flush terminal plane (adjusted OR = 11.8) and distal step (adjusted OR = 9.7) of the second primary molar.

The MO measurements (in millimeters) were compared between the groups, and significant differences were found in regard to AOB ($P = 0.001$) and AO ($P = 0.001$). The average AOB ($P = 0.03$) and AO ($P < 0.001$) were larger in GConv compared to GOrth. In GConv, 74% of the children with AOB presented measurements above 3 mm, versus 52.4% in GOrth. Regarding AO, 69.4% of the children in GConv and 11.1% in GOrth presented measurements above 4.0 mm (Table 5).

The average duration of use was significantly longer for children using conventional pacifiers (27.0 ± 2.1 months) than for children using orthodontic pacifiers (25.8 ± 3.2 months) ($P = 0.033$). Analyses of Pearson's correlation coefficient and the coefficient of determination calculated in linear regression analysis relative to the relationships between MO measurement (in millimeters) and numerical variables (frequency, intensity, and duration of the sucking habit) revealed that duration was the variable that most contributed to the increase of AO. A positive correlation of 0.318 ($P < 0.001$) and 10.1% of determination was found between habit duration and AO occurrence. A strong positive correlation was detected between habit duration and AOB ($R = 0.782$; $P < 0.01$); 61.6% of the AOB size was determined based on the duration of pacifier use.

Discussion

The risk of having MO was higher among the children who used pacifiers compared to non-users. However, differences were not detected in the prevalence of MO between users of

Table 2. Malocclusions (MOs) according to exposure group. São Luís, MA, Brazil. BRISA.

Variables	Total (n = 220)			Pacifier use			Pacifier type			P		
	n	%	n	No (n = 110)		Yes (n = 110)		Orthodontic (n = 55)			Conventional (n = 55)	
				n	%	n	%	n	%		n	%
Malocclusions – horizontal plane												
Normal	133	60.4	79	59.4	54	40.6	31	59.3	23	40.7	0.1501	
Accentuated overjet	81	35.5	27	33.3	54	66.7	23	42.6	31	57.4		
Anterior crossbite	6	4.1	4	66.7	2	33.3	1	50.0	1	50.0		
Malocclusions – vertical plane												
Normal	76	34.5	58	76.3	18	23.7	11	66.7	7	33.3	0.0831	
Deep bite	62	28.2	49	79.0	13	21.0	9	69.2	4	30.8		
Anterior open bite	82	37.3	3	3.7	79	96.3	35	44.3	44	55.7		
Malocclusions – transverse plane												
Normal	133	60.5	83	62.4	50	37.6	28	58.0	22	42.0	0.3581	
Accentuated overjet	78	36.8	26	33.3	52	66.7	24	46.1	28	53.9		
Posterior crossbite	9	2.7	1	11.1	8	88.9	3	37.5	5	62.5		
Anterior open bite (AOB)												
No	117	58.8	96	82.1	21	17.9	15	71.4	6	28.6	0.0272	
Yes	82	41.2	3	3.7	79	96.3	35	44.3	44	55.7		
Accentuated overjet (AO)												
No	117	58.3	72	62.1	44	37.9	26	59.1	18	40.9	0.1072	
Yes	83	41.7	27	32.5	56	67.5	24	42.9	32	57.1		
Deep overbite (DOB)												
No	135	68.3	50	37.0	85	63.0	41	48.2	44	51.8	0.2262	
Yes	63	31.7	49	77.8	14	22.2	9	64.3	5	35.7		
Anterior crossbite (ACB)												
No	195	97.0	96	49.5	98	50.5	49	50.0	49	50.0	>0.9991	
Yes	6	3.0	4	66.7	2	33.3	1	50.0	1	50.0		
Posterior crossbite (MCP)												
No	192	95.5	100	52.1	92	47.9	47	51.1	45	48.9	0.7151	
Yes	9	4.5	1	11.1	8	88.9	3	37.5	5	62.5		
Terminal plane of primary molar												
Mesial step	86	78.9	55	64.0	31	36.0	14	45.2	17	54.8	0.7791	
Distal step	9	8.3	2	22.2	7	77.8	2	28.6	5	71.4		
Flush	14	12.8	2	14.3	12	85.7	5	41.7	7	58.3		
Diastema												
No	117	57.9	61	52.1	56	47.9	25	45.4	30	54.6	0.315†	
Yes	85	42.1	40	47.1	45	52.9	25	55.6	20	44.4		
Crowding												
No	199	98.5	101	50.7	98	49.2	48	49.5	49	50.5	>0.999*	
Yes	3	1.5	0	0.0	3	100.0	2	66.7	1	33.3		

Statistically significant P-values are highlighted in bold ($P < 0.05$).

*Fisher's exact test.

†Chi-square test.

Table 3. Associations between pacifier use (no or yes) and malocclusion (MO). São Luís, MA, Brazil. BRISA.

Variables	Unadjusted*			Adjusted*		
	OR	95% CI	<i>P</i>	OR	95% CI	<i>P</i> [†]
Malocclusions – horizontal plane						
Normal	1.0			1.0		
Accentuated overjet	2.9	(1.6–5.1)	<0.001	3.4	(1.7–6.6)	<0.001
Anterior crossbite	0.7	(0.1–4.1)	0.708	0.6	(0.1–4.0)	0.590
Malocclusions – vertical plane						
Normal	1.0			1.0		
Deep bite	0.8	(0.4–1.9)	0.704	0.9	(0.4–2.2)	
Anterior open bite	85.9	(24.2–305.4)	<0.001	67.5	(18.4–247.4)	<0.001
Malocclusions – transverse plane						
Normal	1.0			1.0		
Accentuated overjet	3.2	(1.8–5.8)	<0.001	39.0	(1.9–7.7)	<0.001
Posterior crossbite	13.0	(1.6–107.2)	0.017	13.3	(1.5–118.6)	0.020
Anterior open bite (AOB)						
No	1.0			1.0		
Yes	121.9	(35.1–423.6)	<0.001	91.2	(25.6–324.8)	<0.001
Accentuated overjet (AO)						
No	1.0			1.0		
Yes	3.3	(1.8–6.0)	<0.001	4.6	(2.2–9.5)	<0.001
Deep overbite (DOB)						
No	1.0			1.0		
Yes	0.2	(0.1–0.3)	<0.001	0.2	(0.1–0.5)	<0.001
Anterior crossbite (ACB)						
No	1.0			1.0		
Yes	0.5	(0.1–2.7)	0.410	0.4	(0.1–2.7)	0.347
Posterior crossbite (MCP)						
No	1.0			1.0		
Yes	8.6	(1.05–70.1)	0.044	9.0	(1.01–80.4)	0.049
Terminal plane of primary second molar						
Mesial step	1.0			1.0		
Flush	10.6	(2.2–50.7)	0.003	17.7	(2.0–153.7)	0.009
Distal step	6.2	(1.2–31.7)	0.028	7.8	(1.4–43.8)	0.020
Diastema						
No	1.0			1.0		
Yes	1.2	(0.7–2.1)	0.476	1.3	(0.7–2.4)	0.476

Statistically significant *P*-values are highlighted in bold (*P* < 0.05). OR, Odds ratio. 95% CI, 95% Confidence interval.

*Having never used pacifiers was the reference category.

[†]Odds ratio adjusted for children's age, gender and family economic class.

conventional or orthodontic pacifiers, except for AOB, which was more common in GConv. Compared to orthodontic pacifiers, use of conventional pacifiers resulted in higher values of the association measurements, which are indicative of more a severe effect on the occurrence of the investigated MO.

To the best of our knowledge, the present study is the first prospective population-based birth cohort that investigated the association between different types of pacifiers and occurrence of MO in the primary dentition, taking the frequency, duration and intensity of the sucking habit and the horizontal,

vertical and transverse occlusal planes into consideration.

As a rule, use of pacifiers begins within the first months of life^{2,6,16,19}. In the present study, 71.8% of the children had started using pacifiers within the first 3 months of life, and most children (70.8%) aged ≥ 30 months old had discontinued their use. These findings agree with the results of several studies that point to a tendency towards reduction of pacifier use parallel to increasing age^{20,21}.

In the present study, prolonged pacifier use was associated with various types of MO in the primary dentition, corroborating the

Table 5. Malocclusion (MO) severity (in millimeters) per pacifier type. São Luís, MA, Brazil. BRISA.

Variables (mm)	Pacifier use			P*
	No (n = 110) Mean ± SD	Yes		
		Conventional (n = 55) Mean ± SD	Orthodontic (n = 55) Mean ± SD	
Accentuated overjet (AO)	2.17 ± 1.00 ^a	3.38 ± 1.70 ^b	2.54 ± 1.22 ^c	0.001
Anterior crossbite (ACB)	2.00 ± 0.00 ^a	4.02 ± 0.87 ^b	3.51 ± 0.98 ^c	0.001
Deep overbite (DOB)	2.98 ± 1.44 ^a	2.80 ± 0.83 ^a	3.41 ± 1.08 ^a	0.550

Statistically significant *P*-values are highlighted in bold ($P < 0.05$). Superscript letters indicate statistically significant differences between groups ($P < 0.05$).

*ANOVA followed by Tukey's test.

results of previous studies^{3,4,22}. The most prevalent types of MO in the primary dentition were AO (41.7%), AOB (41.2%) and PCB (31.7%)^{2,6,16,19,20,23}. The prevalence and intensity of MO were much lower among the children who did not use pacifiers, which confirms the results of previous studies^{1,13,14}. Only two children among the pacifier users did not exhibit MO.

Pacifier use was a risk factor for AOB (adjusted OR = 91.2; 95% CI = 25.6–324.8) and AO (adjusted OR = 4.6; 95% CI = 2.2–9.5). These findings agree with the results of other studies^{3,8,11–14,19,24}. Pacifier use for more than 2 years was described as a risk factor for MO among children three to 6 years old^{1,4,6,24}. Pacifier use is significantly associated with AO^{2,8,19} and mainly with AOB^{2,3,8,11,13,14,16,19,24}, the prevalence rates of which were 96.3% among the pacifier users and just 3.7% in GC in the present study.

The above-mentioned associations might be accounted for by the pressure (forward and upward) exerted by pacifiers on the maxilla, altering the vertical and horizontal maxillary planes, resulting in AOB and AO, respectively. Thus, a lower prevalence of DOB is expected among pacifier users, which was indeed the case in the present study (adjusted OR = 0.2; 95% CI = 0.1–0.5).

Use of pacifiers is also associated with PCB^{1,2,8,19}. In the present study, the odds for PCB were 10.7 times higher among the children who used conventional pacifiers compared to GC (OR = 10.7; $P = 0.040$) and was also observed among pacifier users in

particular ($n = 8$; 88.9%). Adair *et al.*^{2,6} did not detect a difference in the prevalence of PCB between pacifier users and non-users. It is possible that the small sample size in their study did not have enough power to detect such a difference. Some evidence indicates that children have to suck pacifiers for at least 2 years for transverse maxillary alterations to occur²⁵. Continuous presence of the pacifier between the dental arches might alter the maxillomandibular growth parameters, whereby the vertical growth pattern predominates, resulting in an increase of the palate depth and a reduction of the maxillary arch width. Some of these changes persisted well beyond the cessation of the pacifier habits^{3,4}.

Significant differences were not found in the prevalence rates of the assessed types of MO between GConv and GOrth, except for AOB, which was more prevalent in the former ($P = 0.027$). Yet, the adjusted logistic regression analyses detected stronger associations between MO and the use of conventional compared to orthodontic pacifiers. Following adjustment, PCB was associated with the use of conventional pacifiers only (adjusted OR = 10.7; 95% CI = 1.1–102.1), although its prevalence was increased in both GConv and GOrth compared to the GC. Only four studies could be found that compared the frequency of MO in the primary dentition between users of conventional or orthodontic pacifiers^{2,6,8,16}, with controversial results.

In the study by Adair *et al.*², while the prevalence rates of PCB and DOB did not differ between users of conventional or orthodontic pacifiers, the prevalence rates of

AOB and AO did. In their analysis of 79 children aged 24–59 months old, AOB was larger among users of conventional pacifiers ($P = 0.044$), corroborating the results of the present study. However, AO was larger ($P = 0.009$) among users of orthodontic (3.04 ± 0.33) compared to conventional (2.63 ± 0.19) pacifiers and nonusers (2.12 ± 0.25).

In another study⁶, 82 children with a history of use of orthodontic pacifiers were compared to 38 users of the conventional type. The results did not indicate differences in the prevalence rates of either AOB or AO. Similar results were reported by Zardetto *et al.*¹⁶, who concluded that the prevalence rates of alterations in the dental relationships and myofascial structures were higher among the children who suck pacifiers, either conventional or orthodontic, compared to non-users. In turn, Mesomo *et al.*⁷ reported a higher prevalence of PCB among users of orthodontic pacifiers compared to the controls.

In the present and other studies^{2,6,8,16}, use of orthodontic pacifiers was associated with MO, although its anatomical design is considered to be similar to the shape of the maternal nipple during breastfeeding. That association perhaps is partially explained by the fact that children suck pacifiers more often and for longer periods of time compared to the maternal breast, resulting in muscle imbalance, bone disarrangement and movement of the teeth. Therefore, one has to consider children older than 24 months old with NNSHs, independently from the type of pacifier they use. The use of pacifiers should be discouraged vis-à-vis the prevention of MO on the horizontal, vertical, and transverse planes.

Use of either conventional or orthodontic pacifiers was a risk factor for AOB, AO, flush terminal plane and distal step of the primary second molar. DOB protection observed for pacifiers should be considered cautiously, as both protected against DOB, the reason being that the development of AOB resulting from the use of pacifiers does not allow for DOB.

Stronger associations were noted between use of conventional pacifiers and development of these types of MO and PCB. In

addition, MOs were more severe in GConv compared to GOrth (Tables 4 and 5). These findings disagree with the results from Adair *et al.*², who reported significantly greater AO, and from Mesomo *et al.*⁸, who reported a greater frequency of PCB among users of orthodontic pacifiers. The results of the present study also differ from the findings of Zardetto *et al.*¹⁶, who did not find significant differences between users of either type of pacifier. Such divergences might perhaps be partially accounted for in the methodological differences among studies.

As a rule, previous study samples comparing conventional and orthodontic pacifier use were very small^{2,6,8,16} and did not adjust the associations for potential confounders^{2,6,8,16}. In addition, some of the studies included children who had already stopped sucking pacifiers, which might have introduced bias in the assessments. In turn, the present study used a larger, population-based sample, and some strategies to control confounders were applied. Children using both types of pacifiers, those who had already discontinued use, and those who had a history of finger sucking were not included in the analysis. Then, multivariable regression analyses were performed, and the effect measures were adjusted for sociodemographic variables known to be associated with both exposure and outcomes.

In regard to the frequency of pacifier use, as the interviewed mothers were not able to describe the exact number of hours per day of use^{2,16}, we estimated this variable by periods (daytime and/or nighttime). The results indicated that combined use (diurnal and nocturnal) predominated in both GConv and GOrth, without a significant difference⁶. Other authors reported more frequent use at nighttime, although also without a significant difference between groups¹⁶.

As a rule, studies do not assess the intensity of sucking, perhaps due to a lack of precise measurement instruments. In the present study, this variable was assessed in a subjective manner. Most of the interviewed mothers reported that their children did not make a strong effort while sucking the pacifiers, and a significant difference was not found between GConv and GOrth in this regard.

Habit duration was longer in GConv compared to GOrth ($P < 0.05$), which might be related with the greater severity of the MO found in GConv, as habit duration is a relevant factor in the determination of the size of AOB and AO. In this study, duration exhibited positive correlations with both AO ($R = 0.318$; $P < 0.001$) and AOB ($R = 0.782$; $P < 0.001$), while 10.1% of the variation (in mm) in AO and 61.1% of the variation in AOB correlated with the duration of pacifier use. Adair *et al.*⁶ found that habit duration was longer among children with AOB.

The present study exhibits some limitations. Approximately 34.7% of the sample was lost to follow-up from T1 ($n = 5067$ newborn infants) to T2 ($n = 3306$ children), with a higher loss rate among pre-term infants with low birth weight and the ones with poorer socioeconomic indicators. However, there is no evidence that such losses interfered with the analysis of the association between pacifier use and MO. In turn, the present study exhibits several strengths: the sample had sufficient power to estimate the associations of interest; probabilistic sampling was performed, and the simple random sample was selected by means of the lottery method without replacements, which reduced the risk of selection bias; the study population consisted of a prospective cohort, which affords the highest level of evidence among observational study designs; exposure was measured before the effects, thus reducing the odds of memory bias; the examiners were blinded as to the children's status of exposure to minimize any possible tendentiousness; sets of pacifiers were displayed to the mothers to facilitate the collection of the data relative to the type of pacifiers used by the children; the MO measurements were performed by two previously calibrated examiners, with Kappa and intra-class coefficients >0.85 ; several strategies were applied to control for confusion in the inclusion and non-inclusion criteria; and multi-variable analyses were performed.

Conclusions

The risk of having MO was higher among the children who used pacifiers compared to

non-users, mainly for anterior open bite. According to a general trend, the use of conventional pacifiers was associated to severe anterior open bite and overjet compared to use of orthodontic pacifiers. The frequency and intensity of pacifier use were very similar among the investigated children, while habit duration was a strong predictor of MO occurrence and severity.

Why this paper is important to paediatric dentists

- These results highlight the importance of to reaffirm to paediatric dentists that the use of pacifiers increases the risk of malocclusion.
- This paper suggests that malocclusion is associated to sucking habit duration, regardless of orthodontics pacifiers or conventional pacifiers.

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Conflict of interest

The rest of the authors declare no conflict of interests

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