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## Major Article

## The impact of tooth brushing versus tooth brushing and chlorhexidine application to avoid postoperative pneumonia in children



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## Key Words:

Oral hygiene  
Surgery  
Bacterial plaque  
Biofilm

**Background:** The pathogenesis of postsurgical pneumonia is a complicated and multifactorial process, in which elements like oral bacteria, orotracheal intubation, and dental hygiene play an important role. The objective of this study was to evaluate the efficacy of 2 types of oral hygiene interventions in decreasing cases of postsurgical pneumonia.

**Methods:** In pediatric patients scheduled for surgery, a quasi-experimental study was carried out over a 2-year period to evaluate the efficacy of 2 types of oral hygiene interventions. There were 2 groups of intervention with 1 group for comparison. Intervention groups were tooth brushing by a dentist (intervention group 1) and dental brushing by parents + chlorhexidine gluconate (intervention group 2). Data from the year with no oral hygiene interventions were used as the baseline group.

**Results:** A total of 2,535 surgical procedures were followed. Baseline group incidence of postoperative pneumonia was 10 per 1,000 surgeries, 0.2 per 1,000 surgeries in the intervention group 1 ( $P = .04$ ), and 0.8 per 1,000 surgeries in the intervention group 2. Intervention group 1 was protective against postoperative pneumonia (odds ratio, 0.06;  $P = .02$ ; 95% confidence interval, 0.033–0.079), but there was no benefit with intervention group 2 (odds ratio, 0.87;  $P = .599$ ; 95% confidence interval, 0.52–1.46).

**Conclusions:** Dental brushing performed before surgery by a pediatric dentist was effective in reducing the incidence of postoperative pneumonia in pediatric patients.

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Postsurgical pneumonia is a serious and fatal infection that occurs within the first 48–72 hours after orotracheal intubation between 9% and 27% of postoperative patients.<sup>1,2</sup> As the third most common complication in surgical procedures, it is associated with approximately 20%–40% of morbidity, mortality, and prolonged hospital stays, thus considerably increasing hospital costs.<sup>3,4</sup>

Although the pathogenesis of postsurgical pneumonia is multifactorial, oral bacteria is an important factor. Inside the oral cavity, whose function is to maintain the balance of oral health, there are fungi, viruses, and approximately 500–700 different bacterial species, organized as dental bacterial plaque.<sup>5,6</sup> If the balance of the oral cavity is lost, dysbiosis is produced, predominantly allowing

gram-negative organisms with greater virulence to grow.<sup>7</sup> Dysbiosis not only facilitates the presence of dental caries and periodontal disease, but also acts as a trigger for bacteremia and systemic dissemination.<sup>8,9</sup>

This imbalance can be induced by the accumulation and maturation of dental bacterial plaque as a result of deficient oral hygiene, causing local inflammatory disease (gingivitis) if it is located supra-gingival, and periodontitis if it affects the dental support structures; although other factors can interact and influence oral health in intubated patients.<sup>3,7,8</sup> The mere presence of the orotracheal tube in a patient with poor oral hygiene could cause a change in the biochemical composition of the oral cavity, affecting dental bacterial plaque, salivary flow, and dehydrating oral mucosa. Additionally, systemic diseases, stress, and medication related to the management of the underlying condition during critical illnesses can also contribute to dysbiosis.<sup>9,10</sup>

Additionally, the orotracheal tube introduces microorganisms from the oral cavity to the lower respiratory tract during intubation,

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and provides a direct entry route for pathogens, particularly more virulent strains from the oropharynx.<sup>3,6,11,12</sup>

Patients who require mechanical intubation during surgery are therefore exposed to multiple factors that may be associated with an increased risk of postoperative pneumonia.<sup>13–15</sup> To reduce the bacterial load through oral decontamination and therefore reduce the risk of presentation of postoperative pneumonia, different protocols have been implemented, such as tooth brushing and the use of antiseptics and buccal antimicrobials.<sup>16</sup> Oral brushing prevents the maturation of dental bacterial plaque, preventing local inflammation (gingivitis), through mechanical removal of parts of the plaque this decreases the number of microorganisms. However, chlorhexidine, an antiseptic with a broad bactericidal and bacteriostatic spectrum, interacts with anionic receptor sites in the bacterial cell wall.<sup>17,18</sup> The effectiveness of chlorhexidine is also owing to its long-lasting effect, which allows the molecule to remain attached to tissues and have an antibacterial action lasting from 8–12 hours.<sup>18,19</sup>

There are limited studies that have been carried out in the pediatric population to observe the most effective prevention strategies to reduce the incidence of postsurgical pneumonia, considering that most studies have been performed on the adult population or exclusively in cardiovascular surgery.<sup>1,2,20–22</sup> The present study was carried out in a pediatric center offering tertiary care to observe the effects of the implementation of 2 oral hygiene interventions, dental brushing with or without chlorhexidine, on the incidence of postoperative pneumonia.

**METHODS**

We designed a quasi-experimental study to evaluate the efficacy of 2 types of interventions in decreasing postsurgical pneumonia. The Hospital Infantil de México Federico Gómez is a tertiary care teaching hospital devoted to pediatric patients from low or very low-income settings from all over Mexico. It is one of the main national health institutes for pediatric attention; approximately 4,500 major surgeries are performed at the institute on an annual basis. The interventions were implemented as part of a quality improvement strategy for 2 consecutive years, taking into consideration the year before the implementation as the comparative group.

Between interventions, we had a 6-month period without any intervention; this period allowed us to compare the same seasonal periods (summer-autumn) and to avoid the flu season, in which several respiratory viruses are circulating and may confound the results. The strategies were applied to all the patients older than age 1 year

who were scheduled for major and elective surgery that required orotracheal intubation for the procedures. We excluded patients from intensive care areas, emergency rooms, or outpatient surgery. In addition, no patients with respiratory infections, tracheostomy, or mechanical ventilation before the surgery were included.

The study included 3 groups:

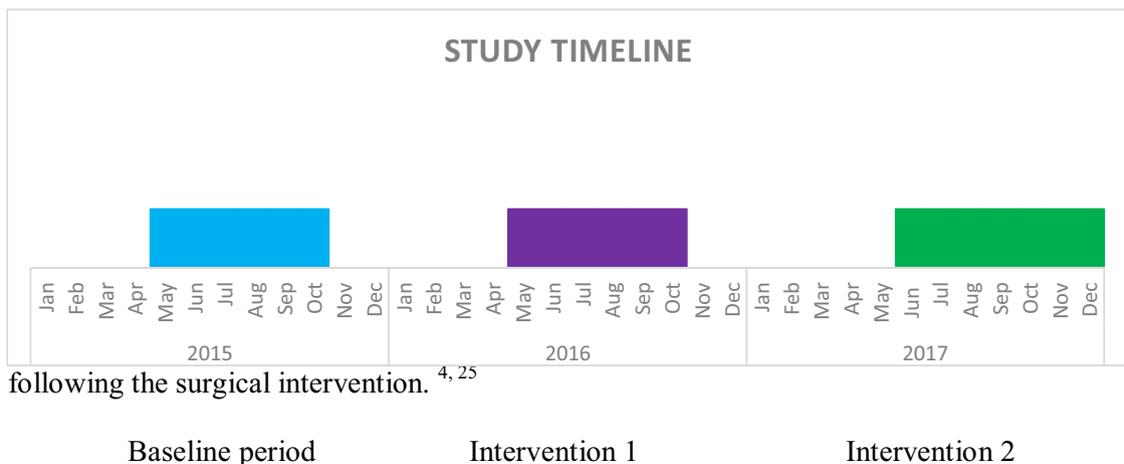
Baseline group: May 1 to October 31, 2015 (Fig 1). In this group, we asked for tooth brushing to be done by the caregiver. Oral cavity exploration was carried out by the resident pediatricians as part of the clinical story, who also requested a consultation with the pediatric dentist when required, according to the patients' clinical criteria.

Intervention group 1: May 1 to October 31, 2016 (Fig 1). During this intervention phase, a resident pediatric dentist (P.G.R.A.) reviewed the patients' oral cavity and brushed their teeth with water according to the dental brushing technique (Table 1) the night before the surgery, and again between 6:00 AM and 7:00 AM on the day of the intervention.

Intervention group 2: June 26 to December 1, 2017 (Fig 1). In this period, a resident pediatric dentist (N.A.V.G.) reviewed the oral cavity and supervised the patients' caregiver, who performed the dental brushing technique in the presence of the researcher (Table 1) the night before the surgery. Between 6:00 AM and 7:00 AM on the day of the surgery, decontamination with 0.12% of chlorhexidine spray was applied instead of tooth brushing (Table 1).

The patients did not have anything to eat or drink between the intervention and the surgery, nor was toothpaste or any mouth rinse used during the intervention period. During the 2 phases, the researcher collected data on caries and periodontal diseases. All the researchers were blinded to the results until the end of the study. The protocol was designed without resources, we had a donation of brushes and could not get paste for all patients, and to homogenize the strategy no toothpaste was used.

For the detection of pneumonia, active epidemiologic surveillance was carried out by the hospital's epidemiology department, as described in De la Rosa-Zamboni et al.<sup>23</sup> Briefly, trained nurses visited the hospital areas twice per week with the purpose of detecting health care-associated infections. Every case was validated by 3 specialists (2 infectious diseases physicians, 1 of them also an epidemiologist, and 1 epidemiologist nurse) according with the ventilator-associated pneumonia (VAP) Centers for Disease Control and Prevention criteria prevailing at the time of the study and Mexican



**Fig 1.** Study timeline. Baseline period: May 1 to October 31, 2015 (995 patients); intervention group 1: May 1 to October 31, 2016 (830 patients); intervention group 2: June 26 to December 2017 (710 patients).

**Table 1**  
Tooth brushing technique and chlorhexidine decontamination protocols

Age (years)	*Tooth brushing technique	**Decontamination with chlorhexidine 0.12%
1-4	Starkey technique <sup>26</sup>	Mouthwash, 5 mL for 1 minute
4-6	Horizontal technique <sup>26</sup>	Mouthwash, 10 mL for 1 minute
6-8	Vertical technique <sup>26</sup>	Mouthwash, 10 mL for 1 minute
8-12	Vibratory technique (Bass technique) <sup>26</sup>	Mouthwash, 10 mL for 1 minute
13-17	Modified Stillman technique <sup>26</sup>	Mouthwash, 15 mL for 1 minute

\*Dental brushing technique used according to the patient's age.<sup>26</sup>

\*\*Oral decontamination with 0.12% of chlorhexidine calculated according to the patient's age. Children aged <6 years with motor limitation to perform rinsing, chlorhexidine gluconate at 0.12% spray per quadrant.

regulations criteria.<sup>24,25</sup> A positive case of postsurgical pneumonia was considered if the patient met the Centers for Disease Control and Prevention criteria for health care-associated pneumonia during the first 3 calendar days after the surgical intervention.<sup>4,25</sup>

### Statistical analysis

For the descriptive analysis of numerical variables, medians and interquartile ranges were used as they were not normally distributed. Proportions were also calculated; to address the differences between proportions we used the  $\chi^2$  test. To understand the effect of the interventions on the postsurgical cases of pneumonia, we calculated the odds ratio and used logistic regression for controlling variables. The baseline period was taken as the reference group. The patients from the intervention 1 and intervention 2 were considered as the intervention groups, which were compared against the rest of the population as well as against the baseline period. A  $P$  value <.05 was considered statistically significant.

## RESULTS

Of 2,701 eligible patients scheduled for surgery, 2,535 (93.6%) patients were included. A total of 3.4% of the patients were not admitted to the hospital, whereas for 2.7% it was not possible to complete the intervention because either the primary care giver or the patient was not present in some of the visits. Of the patients included, 1,125 (44.3%) were girls with a median age of 7 years (confidence interval

[CI], 6.0–7.0), and none of the patients referred allergies to chlorhexidine or were unable to participate. A total of 1,585 (62.5%) patients underwent surgeries that involved a vital organ. A total of 995 patients were from the basal period, 830 from the intervention group 1, and 710 patients from the intervention group 2. There were no differences in age groups between study periods. The intervention groups had slightly more girls (5%–6%;  $P = .02$ ) than the baseline period. The intervention group 1 presented more cardiovascular surgeries than the other groups ( $P < .05$ ), and less transplant surgeries or oncologic surgeries than the other groups ( $P = .007$ ).

### Postsurgical pneumonia

There were 18 episodes of postsurgical pneumonia, 7.1 per 1,000 surgeries. Postsurgical pneumonia was less frequent in the patients from the intervention group 1 (0.2 per 1,000 surgeries,  $N = 2$ ) when comparing it with the basal period (10 per 1,000 surgeries,  $N = 10$ ) ( $P = .04$ ). No differences were found in the incidence of postsurgical pneumonia between the intervention group 2 and the basal period ( $P = .73$ ) (Table 2). No cases of pneumonia were found in transplants or oncologic procedures.

### Effect of intervention group 1 and intervention group 2 on postsurgical pneumonia

Intervention group 1 appears to slightly increase protection ( $P = .06$ ) against postsurgical pneumonia in the univariate analysis, however, in the multivariate analysis intervention group 1 was a strong protective factor against postsurgical pneumonia (odds ratio [OR], 0.18; 95% CI, 0.24–0.825;  $P = .027$ ). Intervention group 2 was not associated with protection against postsurgical pneumonia either in the univariate analysis or the multivariate analysis ( $P > .5$ ) (Table 3).

When the interventions were analyzed against the baseline period, intervention group 1 exhibited a protection for postsurgical pneumonia with a univariate result of  $P = .05$ , that was stronger in the multivariate analysis ( $P = .02$ ) (Table 4).

Heart surgery and neurosurgery were risks factors for postsurgical pneumonia in the univariate analysis as well as in the multivariate analysis (OR, 24.04; 95% CI, 8.13–71.22;  $P < .001$  and OR, 6.45; 95% CI, 1.53–27.2;  $P = .01$ ). In the multivariate analysis they remain important

**Table 2**  
Characteristics of the study population

Age (%)	Total N = 2,535	Baseline period N = 995	Intervention 1 N = 830	$P^*$	Intervention 2 N = 710	$P^\dagger$
<2 years	575 (22.7)	220 (22.1)	146 (20.6)		209 (25.2)	
3–4 years	536 (21.1)	206 (20.7)	141 (19.9)		189 (22.8)	
6–8 years	485 (19.1)	196 (19.7)	124 (17.5)	.331	165 (19.9)	.09
9–14 years	616 (24.3)	236 (23.7)	198 (27.9)		182 (21.9)	
15–19 years	323 (12.7)	137 (13.8)	101 (14.2)		85 (10.2)	
<b>Female sex (%)</b>	1125 (44.30)	408 (41.0)	387 (46.6)	.015	330 (46.3)	.02
<b>Type of surgery</b>						
Gastrointestinal	439 (17.3)	163 (16.3)	156 (18.8)	.092	120 (16.9)	.776
Orthopedic	374 (14.7)	140 (14.0)	113 (13.6)	.778	121 (17.0)	.092
Neurosurgery	202 (7.9)	69 (6.9)	68 (8.1)	.309	65 (9.2)	.093
Urology	195 (7.6)	66 (6.6)	75 (9.4)	.055	54 (7.6)	.439
Cardiovascular	188 (7.4)	61 (6.1)	73 (8.7)	.029	54 (7.6)	.231
Oncologic	109 (4.2)	70 (7.0)	27 (3.2)	<.001	12 (1.7)	<.001
Chest surgery	67 (2.6)	29 (2.9)	30 (3.6)	.399	8 (1.1)	.012
Transplant	11 (0.4)	2 (0.2)	1 (0.1)	.672	8 (1.1)	.013
Ear-nose-throat	388 (15.3)	169 (16.9)	104 (12.5)	.007	115 (16.2)	.666
Ophthalmology	259 (10.2)	104 (10.4)	86 (10.3)	.949	69 (9.7)	.62
Plastic surgery	208 (8.2)	81 (8.1)	72 (8.6)	.681	55 (7.7)	.767
Stomatology	95 (3.7)	41 (4.1)	25 (3.0)	.206	29 (4.1)	.97
<b>Postsurgical pneumonia (N/1,000 surgeries)</b>	18 (7.1)	10 (10.0)	0.2 (2.4)	.04	0.8 (8.4)	.73

\*The  $\chi^2$  test between the intervention group 1 and the baseline period.

†The  $\chi^2$  test between the intervention group 2 and the baseline period.

**Table 3**  
Risk factors for postsurgical pneumonia among the study population

	Univariate analysis			Multivariate analysis		
	OR	P	95% CI	OR	P	95% CI
Age group	0.79	.14	0.57-1.08	0.77	.16	0.53-1.11
Cardiovascular	24.04	<.001	8.13-71.22	24.91	<.001	8.32-74.56
Neurosurgery	6.45	.01	1.53-27.20	6.829	.009	1.61-28.97
Periodontal disease*	3.09	.146	0.6-15.4	NV	NV	NV
Teeth with dental caries*	1.61	.55	0.32-8.0	NV	NV	NV
Brushing x 2	0.24	.06	0.051-1.09	0.18 0	.027	.04-0.825
Chlorhexidine	0.84	.74	0.30-2.32	0.747	.58	0.26-2.11

CI, confidence interval; NV, not valuable; OR, odds ratio.

\*The registry of dental evaluation was carried out just in the intervention periods, N = 1,540, and was therefore not included in the multivariate analysis.

**Table 4**  
Effect of intervention 1 and intervention 2 on postsurgical pneumonia against the baseline period

Groups	Univariate analysis			Multivariate analysis		
	OR	P	95% CI	OR	P	95% CI
Baseline period						
Intervention group 1	0.22	.05	0.48-1.01	0.06	.02	0.033-0.0790.079
Intervention group 2	0.84	.7	0.30-2.32	0.87	.599	0.52-1.46

Effect of intervention 1 and intervention 2 on postsurgical pneumonia against the baseline period by univariate and multivariate analyses.

CI, confidence interval; OR, odds ratio.

**Table 5**  
Patients reported with postoperative pneumonia in the first 72 hours

Patient	Age (years)	Intervention group	Service	Isolation of pathogen
1	3	1	Cardiovascular	No
2	4	1	Cardiovascular	No
3	1	1	Neurosurgery	No
4	4	1	Orthopedic	No
5	1	1	Cardiovascular	No
6	13	1	Cardiovascular	No
7	2	1	General surgery	No
8	1	1	Neurosurgery	<i>Klebsiella pneumoniae</i>
9	4	1	Cardiovascular	Rhinovirus/respiratory syncytial virus
10	6	1	Cardiovascular	No
11	2	2	Cardiovascular	No
12	8	2	Neurosurgery	No
13	17	2	Orthopedic	No
14	2	2	Cardiovascular	No
15	2	2	Cardiovascular	No
16	13	2	General surgery	No
17	15	2	Ear-nose-throat	<i>Enterobacter cloacae</i>
18	15	2	Cardiovascular	No

A total of 18 patients reported with postoperative pneumonia in the first 72 hours, including patient age, service, and isolation of pathogen.

risk factors. However, the other types of surgical procedures were not associated with postsurgical pneumonia either in the univariate or in the multivariate analysis. Age, periodontal disease, and tooth caries were not related with postsurgical pneumonia ( $P \geq .1$ ) (Table 3).

## DISCUSSION

To our knowledge, this is the first study that addresses the problem of postoperative pneumonia in children and analyzes the effect of preoperative tooth brushing compared with chlorhexidine. This study provides 2 relevant findings. First, we found that although dental brushing performed by a professional the night before and the day of surgery protected against postoperative pneumonia, there was no effect when chlorhexidine was used replacing morning brushing.

Second, cardiovascular surgery and neurosurgery are independent risk factors for developing postoperative pneumonia in children.

Chughtai et al<sup>2</sup> performed a systematic review, in which they reported variable frequencies of postoperative pneumonia according to the type of surgery that was performed. The authors reported the highest rates of postoperative pneumonia in cardiovascular surgery (2%-54%), orthopedics (0.44%-14.4%), general surgery (0.54%-27%), and neurosurgery (5.6%-9.1%). The articles of this systematic review and the data of various authors (Zolldann et al,<sup>27</sup> Jiang et al,<sup>28</sup> and Agarwal et al<sup>29</sup>) have reported high prevalence of nosocomial pneumonia in postoperative patients after cardiovascular surgery and neurosurgery. We also found the highest prevalence of postsurgical pneumonia in these 2 groups of patients: 9.8% and 2.8%, respectively, for postoperative cardiovascular surgery and neurosurgery. It is probable that risk factors of pneumonia are more prevalent in patients with

cardiovascular pathologies (pulmonary water overload, trans-surgical hypothermia) and neurosurgical disorders (high consciousness, damaged protective reflexes, among others) and contribute to an increased risk<sup>30</sup> and altered immunologic status in patients with heart disease.

It has been demonstrated that the bacteria present in the oral microbiome is responsible for the colonization of the orotracheal tube; this microbiome is found in the dental bacterial plaque.<sup>31</sup> Several studies have shown microbiological changes that are observed in the biofilm of dental bacterial plaque after intubation, with replacement of oral flora by respiratory pathogens that facilitate the development of respiratory infections.<sup>32,33</sup> In this way, dental bacterial plaque not only plays a role in the onset and progress of gingival inflammation, but is also linked with systemic diseases such as postoperative pneumonia, which occurs after orotracheal intubation of patients scheduled for surgery.<sup>34,35</sup>

It has been shown that tooth brushing alone has a marginal effect in avoiding VAP.<sup>1,2</sup> De Lacerda Vidal et al<sup>32</sup> demonstrated that tooth brushing, added to the use of chlorhexidine, does have an effect in reducing the incidence of VAP against the use of chlorhexidine without brushing. Finally, Fields<sup>36</sup> showed that dental brushing alone reduced cases of VAP in patients in neurologic intensive care units (4.2%-0.62%), although there was a lack of appropriate follow-up by nurses that performed oral hygiene. Although these studies were conducted on adults, they seem to indicate that an important component to avoid VAP is the mechanical removal of the biofilm, even in a population with more complex biofilms such as adults.<sup>37-41</sup> Our data suggests that ensuring an adequate removal of the biofilm with a correct brushing technique according to the patients' age may be sufficient to reduce the risk of postoperative pneumonia in children, even in complex surgeries.

However, according to a Cochrane review in 2016, rinsing with chlorhexidine with or without tooth brushing was effective in reducing VAP from 18%-12%.<sup>16</sup> However, the review included few studies on children. Jácomo et al,<sup>4</sup> in a randomized double-blind study, evaluated the effect of oral hygiene with chlorhexidine gluconate at 0.12% on the incidence of nosocomial pneumonia and VAP in children under 12 months undergoing cardiac surgery, without finding an effect, although the authors attribute the lack of effect to the majority of their patients being edentulous. Sebastian et al<sup>31</sup> also found no effect in decreasing VAP in intensive therapy patients from age 3 months to 15 years. Kusahara et al<sup>41</sup> in 2012 evaluated the effectiveness of oral care with chlorhexidine at 0.12% in the decrease of VAP in critically ill children in the chlorhexidine group (oral care with a toothbrush and an antiseptic gel twice a day) and the placebo group (oral care with a toothbrush and a nonantiseptic gel twice a day) and found that the use of 0.12% chlorhexidine did not significantly change the incidence of pneumonia in a sample of mechanically ventilated children. Our results in postoperative pneumonia coincide with those of these authors because we also did not find an effect when using chlorhexidine.

It should be noted that in both interventions we performed the brushing the night before the procedure and on the morning of the surgery. What changed was the person who did the brushing. Although in the successful intervention, the brushing was performed by the resident pediatric dentist, in the other group it was the relative of the patient supervised by the resident pediatric dentist. It has been previously described that even when the proper tooth brushing technique is known, it is not always enough to ensure that it is performed properly.<sup>35</sup> It is possible that the brushing performed by a pediatric dentist ensures the use of the correct technique on all occasions, whereas the brushing done by the patients' caretaker was not so meticulous and would influence its lack of effectiveness.

There are some logistic points to consider. There was good compliance by the patients and parents toward the procedure, although

caregiver assistance was required in some cases, as in children under 3 years of age or in children with physical or mental disabilities. The hospital did not have extra costs because it was the resident of pediatric dentistry who performed the intervention. However, it is possible that not all hospitals have such services. In our study, the parents were trained at bedside at the time of the intervention, but there was no formal training or evaluation of the technique. It is possible that formal training of primary caregivers or other personnel (eg, nurses) improves the results of the intervention and makes it feasible to apply in other places. Finally, it is very important to recognize that the nursing staff does not usually monitor compliance with tooth brushing within routine general care. In our study it was necessary to specify it as a separate indication in medical orders.

This study has several limitations. First, it is not a randomized controlled study. A historical control group with similar characteristics, who were treated in the same hospital but at an earlier time, and did not receive oral decontamination, was compared with a group of patients subjected to 2 quality strategies. Nevertheless, we were able to confirm that in the 3 periods analyzed, the measures adopted to prevent VAP did not vary, nor did the percentage of adherence to hand hygiene (66%-77%). In addition, we considered it unethical that a group of patients would be denied the possibility of decreasing the bacterial load of the plaque before a high-risk procedure. It is important to point out and consider the kind of population that was included in the sample, most of the patients had complex pathologies and poor oral hygiene. Therefore, the results cannot be generalized to every pediatric patient. Another limitation was that in the first group, a report of the oral condition was not made (presence or absence of caries and periodontal disease), and only verbal indications of the cleanliness were given and interservice consultation was given if necessary. Even so, the presence of periodontal disease or caries did not prove to be a risk factor in the incidence of postoperative pneumonia.

## CONCLUSIONS

To our knowledge, this is the first study on children that analyzes the effects of preoperative tooth brushing against the use of chlorhexidine in reducing the incidence of postoperative pneumonia. We effectively discovered that presurgical brushing performed by a pediatric dentist on 2 occasions, without the use of mouthwash, toothpaste or antiseptics, almost eliminated postsurgical pneumonia that suggests that the most important factor in avoiding postoperative pneumonia is the appropriate mechanical removal of the plaque. We consider that the findings of our study are sufficient to show that the policies of preoperative care in children can include vigilance of dental brushing according to the appropriate technique for the age group and, preferably, by a pediatric dentist the night before the intervention and on the day of surgery.

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