Evidence to Support Tooth Brushing in Critically Ill Patients

By Nancy J. Ames, RN, PhD, CCRN

Tooth brushing in critically ill patients has been advocated by many as a standard of care despite the limited evidence to support this practice. Attention has been focused on oral care as the evidence accumulates to support an association between the bacteria in the oral microbiome and those respiratory pathogens that cause pneumonia. It is plausible to assume that respiratory pathogens originating in the oral cavity are aspirated into the lungs, causing infection. A recent study of the effects of a powered toothbrush on the incidence of ventilator-associated pneumonia was stopped early because of a lack of effect in the treatment group. This review summarizes the evidence that supports the effectiveness of tooth brushing in critically ill adults and children receiving mechanical ventilation. Possible reasons for the lack of benefit of tooth brushing demonstrated in clinical trials are discussed. Recommendations for future trials in critically ill patients are suggested. With increased emphasis being placed on oral care, the evidence that supports this intervention must be evaluated carefully. (*American Journal of Critical Care.* 2011;20:242-250)

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Tooth brushing is a common activity for health promotion and disease prevention that is performed daily by most people. Therefore, it would seem logical that patients who are critically ill and cannot brush their own teeth would have this intervention performed by the nurse who is caring for them. However, strong evidence supporting the benefit of tooth brushing in intubated, critically ill patients is lacking. Conversely, tooth brushing may allow bacteria to enter the bloodstream because of potential breakdown of mucosal and gingival tissue, especially in patients with poor dental health.[1-5] In addition, in a recent review[6] of the association between oral care and bloodstream infections in patients receiving mechanical ventilation, researchers concluded that additional research is needed in order to explore this association.

Evidence is accumulating from these studies, which use molecular methods that can genetically match bacteria obtained from oral specimens to organisms identified in the blood.[1] One concern is the possibility that, owing to the nature of their critical illness, critically ill patients are already immunocompromised, and tooth brushing might expose these patients to the risk of bacteremia without any benefit.[7] In contrast, in elderly persons who reside in nursing homes, evidence suggests tooth brushing decreases the incidence of pneumonia and decreases mortality rates.[8] Numerous studies of elderly persons who routinely received professional oral care have demonstrated improved outcomes: fewer febrile days and decreased rates of influenza or pneumonia.[9-11] The critical care population and elderly persons share many characteristics. It is plausible that tooth brushing in critically ill patients would demonstrate a benefit.

The purpose of this review is to summarize the evidence on the effect of tooth brushing in critically ill adults and children receiving mechanical ventilation. This review examines the evidence demonstrating the effect of tooth brushing in clinical trials of critically ill patients, discusses possible reasons for the lack of benefit demonstrated in these trials, and offers recommendations for future trials in critically ill patients. With the increased emphasis being placed on oral care, it is important to evaluate the evidence that supports this intervention carefully.

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Tooth Brushing as a Standard of Care

Tooth brushing is a necessary activity in order to maintain oral health. Twice daily tooth brushing is the recommendation of the American Dental Association in order to maintain oral health.[12] Without brushing, plaque accumulates in the subgingival crevices of the teeth and causes gingival inflammation and bleeding.[13] During periods of illness, tooth brushing is sometimes relegated to a lower priority and often forgotten. When a patient is critically ill, oral care, if performed at all, becomes a nursing function. This intervention is complicated when a patient is orally intubated. Brushing the teeth becomes a challenge for the nurse because of the presence of the endotracheal tube and orogastric tubes in the patient's mouth.

> Tooth brushing may allow bacteria to enter the bloodstream, especially in patients with poor dental health.

Recently, because of a potential association between pathogenic bacteria in the mouth and those same bacteria identified in the lungs, various professional groups have advocated brushing the teeth of intubated patients to prevent pneumonia, especially ventilator-associated pneumonia (VAP).[14,15] Tooth brushing has been recommended as an important intervention in critically ill patients to remove the plaque biofilm that is a potential nidus of infection.[16] However, conflicting information is available on which type of oral care to perform, the agents that should be used, and the frequency of oral care.

Numerous reviews[17-20] have summarized the frequency and type of tooth brushing and the oral additives that produce effective plaque removal in healthy persons. It is clear from these reviews that twice daily brushing removes most plaque in healthy volunteers without periodontal disease. Researchers in other studies have examined what happens in the

oral cavity when no brushing is performed. After 4 days without any brushing, inflammation and exudate are present in the gingival tissues.[21] Once cleaning was resumed, however, the gingival inflammation subsided within 7 days. In a study of toothbrushing frequencies, tooth brushing at 48-hour intervals prevented gingivitis.[22] In that study, the 30 student volunteers were checked, after brushing, by a dental hygienist for the appropriateness of their cleaning as part of the research protocol. In a more recent study,[23] researchers examined the growth of bacteria in 10 healthy volunteers who abstained from brushing for 4 days after an extensive preparatory period during which they received extensive professional tooth cleaning. Plaque was measured on days 0, 1, 2, and 4 during the no-brushing phase. Plaque and the number of bacteria in the plaque had increased by day 4. The number of bacteria increased, as did the presence of bacterial species that have been linked to periodontal disease.[23]

Powered toothbrushes with a rotation oscillation action reduce plaque and gingivitis more effectively than manual toothbrushes.

With the advent of powered toothbrushes, the question was asked whether or not these devices improve plaque removal. In a recent Cochrane meta-analysis,[24] results of 42 trials involving 3855 participants from the general public indicated that powered toothbrushes with a rotation oscillation action reduced plaque and gingivitis more than did manual toothbrushes.

Methods

PubMed, CINAHL Plus, EMBASE, and Scopus databases were searched for pertinent research studies that were published in English regarding tooth brushing and critical care. The search was not limited by publication date. PubMed produced 14 results. EMBASE did not yield any unique relevant citations. Searches of CINAHL Plus supplied the most citations with 29, and Scopus resulted in 26 citations. Many of these were duplicates of the PubMed database or short review articles published in journals that were not peer reviewed. The majority were not research studies. The following search strategies were used. The first search strategy used (*Toothbrushing* OR *"tooth brushing"* OR *"brushing teeth"*) and (*ICU* OR *intensive care*[MeSH] OR *"intensive care"* OR *intensive care units*[MeSH] OR *"intensive care unit"* OR *"intensive care units"* OR *critical care*[MeSH] OR *"critical care"*), and the second search used (*tooth* OR *teeth*) AND (*brush* OR *brushing*) AND (*ICU* OR *intensive care*[MeSH] OR *"intensive care"* OR *intensive care units*[MeSH] OR *"intensive care unit"* OR *"intensive care units"* OR *critical care*[MeSH] OR *"critical care"*). Only studies that recruited patients receiving mechanical ventilation were included in the review. Because of the lack of randomized control trials, observational studies were included. Two randomized studies[25,26] that used tooth brushing performed in hospitalized, surgical patients were excluded because the samples in those studies consisted of surgical patients who were not admitted to critical care units. Numerous other surveys or observational studies of nurses' oral care practices also were excluded because those studies focused on nurses' opinions regarding oral care and not the effects of tooth brushing on VAP.

Results

The Table summarizes the 8 studies included in this review. Five of the 8 studies had some measure of a positive outcome in tooth brushing and oral care as an intervention in patients with VAP. Three randomized trials[27-29] and 1 large case control trial[30] (n = 1666) measured outcomes of VAP, ICU length of stay, duration of mechanical ventilation, bacterial profile, or ICU mortality rate. Three of the studies[31,32,34] were designed as observational studies comparing infection rates before and after an intervention that was instituted in the designated critical care unit. One observational study[33] began as a randomized clinical trial and became a quality improvement project. One of the observational studies[34] was published in abstract form and did not list the number of research participants. In all 4 of these observational studies,[31-34] VAP rate was an outcome measure. Of the 8 studies included in this review, 1 study[28] was performed in a pediatric ICU in Brazil and included 9 nonintubated children. "Nonintubated" was defined by the researchers as a child intubated for fewer than 24 hours. Only 1 study[27] was performed in more than 1 critical care unit. Medical, surgical/trauma, and neuroscience critical care units were represented.

Discussion

Tooth Brushing as an Intervention in Critically Ill Intubated Patients

Tooth brushing was included in each of the 8 studies reviewed. Besides this intervention, other oral care practices were performed in each of the reviewed studies. Two of the 3 randomized control studies[27,29] that were reviewed showed no difference in study outcomes when patients who had tooth brushing were compared with control groups. The third randomized controlled trial[28] that was reviewed,

Table
Summary of clinical trials about patients using tooth brushing as an intervention

Source	Type of trial	Sample	Method/results
Munro et al,[27] 2009	Randomized controlled trial	471 patients receiving mechanical ventilation; 3 critical care units: medical, surgical/trauma, neuroscience	Patients receiving mechanical ventilation were randomized to 4 groups: (1) usual care (2) tooth brushing 3 times a day (3) chlorhexidine (0.12%), 5 mL by oral swab twice daily and (4) chlorhexidine and tooth brushing performed 3 times a day. Chlorhexidine **was significant** in reducing the incidence of ventilator-associated pneumonia as measured by the Clinical Pulmonary Infection Score on day 3. No other intervention was significant.
Pedreira, et al,[28] 2009	Randomized controlled trial	56 children in a pediatric intensive care unit	Children who were receiving mechanical ventilation were randomized into 2 groups: (1) Oral care with **brushing teeth** and tongue, placebo gel applied and (2) experimental group included oral care with **brushing teeth** and tongue and oral chlorhexidine gel treatment. Oral care provided twice a day. Outcome measures demonstrated **no difference** in bacteria, duration of mechanical ventilation, or length of stay in the unit. Nine children received mechanical ventilation for less than 24 hours.
Pobo et al,[29] 2009	Randomized controlled trial	147 patients receiving mechanical ventilation; medical-surgical intensive care unit	Patients receiving mechanical ventilation were randomized into 2 groups: (1) standard oral care every 8 hours that was applied to teeth, tongue, and mucosal surfaces with 0.12% chlorhexidine and 10 mL of chlorhexidine injected intraorally and aspirated after 30 seconds and (2) tooth brushing group had standard oral care plus powered toothbrush with chlorhexidine as described. Brushed teeth and gumline every 8 hours. Outcome measures demonstrated **no difference** in microbiologically documented rates of ventilator-associated pneumonia, mortality, antibiotic-free days, length of stay in the intensive care unit, or duration of mechanical ventilation.
Mori et al,[30] 2006	Case control	1666 adults receiving mechanical ventilation; medical-surgical unit	Study compared 2 groups : (1) historical controls (n = 414) who received no systematic oral care and (2) intervention group (n = 1252) that received oral care 3 times a day. A written protocol directed oral care that included tooth brushing and rinses with povidone-iodine 3 times a day. Results showed **decreased incidence of ventilator-associated pneumonia** in the oral care group. The relative risk of ventilator-associated pneumonia was decreased in the oral care group.
Garcia et al,[31] 2009	Pre/post intervention observational study	1538 adults receiving mechanical ventilation; medical intensive care unit	Study compared 2 groups: (1) controls (n = 779) in a unit that had no oral procedures for preventing ventilator-associated pneumonia (eg, oral assessments, suctioning of subglottic space, or tooth brushing) and (2) intervention period instituting oral care techniques for prevention (n = 759) in the same unit. Oral care consisted of oral assessment, deep suctioning every 6 hours, oral cleaning every 4 hours and tooth brushing twice a day. **Rates of ventilator-associated pneumonia decreased** from 12 to 8 (per 1000 ventilator days). Mortality and length of stay in the intensive care unit decreased in the group measured after institution of oral protocols.

continued

Table *continued*

Source	Type of trial	Sample	Method/results
Sona et al,[32] 2009	Pre/post intervention observational study	1648 adults receiving mechanical ventilation; surgical intensive care unit	Study compared (1) rates of ventilator-associated pneumonia in all patients receiving mechanical ventilation during a preintervention period (n=777) and (2) rates after institution of oral care interventions (n=871). Interventions during study period included tooth brushing for 1-2 minutes at 12-h intervals with sodium monofluorophosphate 0.7% paste. Used stock tooth brush. Applied 15 mL of 0.12% chlorhexidine solution. **Oral protocol compliance (70%-90%)**; rates of ventilator-associated pneumonia decreased in study period from 5.2 to 2.4 infections/1000 ventilator days (P=.04); ventilator days decreased for study period (P=.001).
Fields,[33] 2008	Observational study	345 adults receiving mechanical ventilation; stroke, neuroscience, medical unit	**Tooth brushing** 1 minute 3 times a day along with other interventions that included subglottic drainage decreased ventilator days and rates of ventilator-associated pneumonia. Study started as a randomized controlled trial but evolved into a quality improvement project.
McLellan et al,[34] 2007	Pre/post intervention observational study	Unknown number of adults receiving mechanical ventilation in a medical intensive care unit	Study compared 2 groups: (1) patients who had ventilator-associated pneumonia during a preintervention period with (2) all patients receiving mechanical ventilation after institution of stringent oral care. Oral care protocol included tooth brushing every 12 hours and oral care cleansing every 2 hours. **Compliance with tooth brushing was only 47%**. VAP rates decreased for this unit. Presented in abstract form.

which involved patients in a pediatric ICU, did not compare tooth brushing with a control group. In one study,[27] a significant difference in VAP was measured by a clinical score on 1 day of the study, but this difference was not in the tooth-brushing group. In addition, some important details of these studies must be analyzed because these details affected the outcomes of the studies and provide information for future study design.

In the most recent study,[27] Munro and colleagues randomized critically ill intubated patients into 4 groups (see Table). Two of the 4 groups included tooth brushing. The purpose of this study was to examine the effects of tooth brushing, use of chlorhexidine, or both on the incidence of VAP. These researchers defined VAP as a Clinical Pulmonary Infection Score (CPIS) of 6 or greater, with a range of possible scores from 0 to 12. The CPIS includes body temperature, white blood cell count, findings on chest radiography, and results of microbiological examination of tracheal secretions; CPIS has been used in many clinical studies to define VAP.[35] Patients were followed for 7 days. The researchers obtained consent from 547 patients, but only 471 patients were receiving mechanical ventilation on day 1 of the study. Extubation and transfer out of the critical care unit were 2 reasons that patients were removed from the study. Because of this attrition and missing data, only 192 patients were in the final analysis.

Despite the exclusion of patients who already had pneumonia when consent was obtained, many patients met the criteria for pneumonia (CPIS ≥6) when data collection began. The researchers described this finding as unexpected. Later in the analysis, 2 subgroups were identified, namely, patients who had VAP at baseline and patients who did not. It was in the subgroup of 87 patients who did not have pneumonia (CPIS <6) at baseline that, on day 3 of the study, chlorhexidine oral swabs significantly decreased the incidence of VAP. The fact that study personnel provided tooth brushing and chlorhexidine treatments to all patients is noteworthy. These interventions were not provided by the nurses caring for the patients. Despite the researchers' having maintained the integrity of the intervention, tooth brushing produced no significant change in the incidence of pneumonia in this well-controlled study. The strengths of this study include the large number of patients enrolled and the fact that the study personnel provided the interventions. An additional outcome measure for VAP, such as a

microbiological definition of pneumonia, would have strengthened the study.

In a study of patients in a pediatric ICU,[28] both patients in the control group and patients in the intervention group received tooth brushing. The intervention group added the application of chlorhexidine gel (0.12%). The control group used a placebo gel. Both groups applied the gel with a toothbrush after brushing the oral cavity (see Table). The purpose of this study was to determine whether the microbiological profiles differed between the 2 study groups. Compliance was evaluated but not reported. As mentioned, 9 children were intubated for less than 24 hours. These children were not excluded from the study. The mean age of patients in the study sample was 2.3 years, but no information is given on the range of ages for the patients who were included. VAP rates were not assessed in this study. Length of stay and days of mechanical ventilation were compared between the 2 groups. Most of the children were listed as having an "infectious disease" at the time of admission. The researchers did not define what was meant by infectious disease.

The purpose of that study[28] was to compare microbiological profiles between the 2 groups. To that end, oral samples were collected from the tonsillar area and the upper posterior part of the oropharynx during the first 24 hours of admission to the pediatric ICU and 3 other times during the study. Qualitative results of standard cultures were recorded. Although pathogenic colonization did not differ significantly between the 2 groups, a list of the bacterial organisms that were identified was provided. Forty percent of the children in this study were colonized with aerobic pathogens within 24 hours of admission. Four days after admission, 50% of the children had oral cavities that were colonized with potential respiratory pathogens. These data reflect what has been noted in the adult studies,[36,37] but this study is one of the first in the pediatric literature to describe the oral environment. This description of the oral microbiome of intubated children is one of the study's strengths. Tooth brushing might have affected VAP rates in these children, but there was no control group or standard-care group with which to compare. Further, the addition of chlorhexidine to the treatment groups did not change any of the outcomes of the study, including the microbiological profile, length of stay, and days of mechanical ventilation. The researchers stated that one limitation of the study was the small sample size. Generalization of the findings in that study to other pediatric populations is difficult because the age ranges were not reported.

Pobo et al[29] designed a randomized controlled trial to test the effect of a powered toothbrush on VAP incidence. A total of 147 patients were randomized into 2 groups: standard oral care and standard oral care plus powered tooth brushing (see Table). VAP was defined not only by clinical criteria but on the basis of a microbiological diagnosis. The 2 groups did not differ with regard to the outcome variables of VAP, mortality, or duration of mechanical ventilation. In this study, addition of the powered tooth brush did not change the incidence of VAP. This study was stopped after a planned interim analysis revealed no difference between the 2 groups. The researchers cited that the unit where the study took place had a low incidence of VAP before the study began. The incidence of VAP in the study was 22.4%. This low incidence of VAP prevented them from demonstrating a difference between the 2 groups with their projected sample size. They estimated that a study population of 1500 intubated patients would have been required to demonstrate the effect of tooth brushing on VAP.

> In a well-controlled study, tooth brushing produced no change in pneumonia incidence.

One of the strengths of that study was the addition of a confirmed diagnosis of VAP based on culture data. Limitations include lack of any measure to verify the compliance of the nursing staff with the study protocol. This apparent failure to manage the integrity of the intervention could be another reason that this study demonstrated no difference between groups. This lack of intervention integrity was a threat to the internal validity of the study.[38] It is analogous to studying the effects of a drug in a clinical trial in which a percentage of the patients who were scheduled to receive the experimental agent did not receive this agent. Managing this threat to internal validity in a rapidly changing environment such as a critical care unit is difficult. Nursing personnel who are responsible for caring for patients are now tasked additionally with study interventions. Realistic strategies addressing these threats to the validity of clinical research focus on assessment of the environmental stability and ways to manage this instability.[39]

> In one study, 40% of children were colonized with aerobic pathogens within 24 hours of admission.

Another issue with this study was the sequence of interventions performed. The methods section contains no information on which intervention was performed first in the tooth-brushing group. It would have been important to perform the tooth brushing

first and then apply the chlorhexidine. Although the researchers stated that no adverse events were associated with either tooth brushing or chlorhexidine use, no definition of adverse events is given.

In the remaining 5 studies[30-34] in this review, the effects of tooth brushing on VAP were assessed by using a VAP rate measured retrospectively. Many different variables other than tooth brushing could have intervened to change the VAP rate. For example, new equipment or innovative ventilator weaning procedures that were not available before the intervention could have affected the VAP rate. Researchers cannot control these confounding variables that introduce biases that affect the validity of the study. For this reason, the results of these studies should not be viewed in the same way as a prospective, randomized trial where the outcomes for both the control and the treatment groups are measured during the same time period.[40]

Many of these studies did not report protocol compliance or did not measure it.

In a large case control study,[30] patients receiving oral care, including tooth brushing, were compared with historical control subjects who received no systematic oral care. The purpose of this study was to evaluate the effects of oral care on prevention of VAP. A strict oral care protocol was outlined in the study (see Table). The incidence of VAP was significantly lower in the oral care group than in the group that received no protocolized oral care. The incidence of pneumonia (per 1000 ventilator days) was 3.9 in the oral care group and 10.4 in the control group. The number of ICU days before the onset of VAP was also significantly different in the oral care group.

One of the strengths of this study was an attempt by the researchers to identify the bacteria that are linked to VAP. They examined 15 patients from the oral care group and described the bacteria that were identified. However, other long-term outcome measures such as days of mechanical ventilation and ICU length of stay were not significantly different from the values in the historical control subjects. The results of this study are encouraging. These researchers maintained the integrity of the intervention by using a dentist and nursing staff to provide the oral care. However, the study lasted more than 8 years. This long study duration might have biased the results as improvement in the care, institution of new mechanical ventilator protocols, or both could have produced a decrease in VAP rates. Although the effect of tooth brushing alone was not measured, this study did demonstrate a positive outcome for an oral care protocol when compared with a historical control group.

Two other studies[31,32] with a similar design compared VAP rates before and after an intervention that included institution of a protocol for oral care. Both studies attempted to demonstrate a decrease in VAP with the institution of an oral care protocol, and both studies demonstrated a difference in VAP rates presumably affected by the oral care protocol. The frequency of VAP was reduced 46% in the study by Sona et al,[32] which was a significant difference. In the study by Garcia et al,[31] VAP rates decreased in the postintervention period but the changes were not significant. Outcome measures related to mortality, duration of ventilation, time to VAP, and length of stay in the ICU decreased significantly after the interventions. The study by Garcia et al is the only study in the review that showed a difference in long-term outcome measures.

Similar oral care protocols were used in both studies. In the study by Garcia et al,[31] besides tooth brushing every 12 hours, a new oral care system for suctioning was introduced, and the oral protocol required suctioning every 6 hours and oral cleaning every 4 hours. In the study by Sona et al,[32] tooth brushing was performed every 12 hours (see Table). Staff nurses performed the oral care in both studies. In the study by Sona et al, compliance with the oral protocol was monitored and was between 70% and 90%; in the Garcia protocol, compliance exceeded 80%. The strength of these 2 studies was their emphasis on compliance of the nursing staff with the study protocol. The compliance of the nursing staff was commendable in both these studies, and its effect on the results is apparent.

In the study reported by Fields,[33] patients were followed in a quality improvement project that began as a randomized trial. The oral intervention included brushing the teeth every 8 hours, and other VAP interventions were instituted at the same time. The oral care group was compared with a control group that was provided oral care but no tooth brushing. Because the VAP rate decreased to 0.065% in 345 patients with 1850 ventilator days, the study was stopped and all patients received tooth brushing. No other data or analysis was provided for the original 345 patients. No clear definition of VAP was provided in that article. Obviously, it would have been preferred from a study perspective if the randomized trial that Fields had started had been completed.

Finally, in an abstract reported at a national meeting, McLellan et al[34] reported a stringent oral protocol that included cleansing of the oral cavity every 2 hours and brushing of the teeth every 12

hours. Protocol compliance was reported at 70% with oral care every 2 hours but only 47% adherence with tooth brushing. Despite this lack of compliance, the group reported a 54% reduction in VAP rates. Again, how VAP was diagnosed and the definition of VAP were not mentioned in this abstract.

Future Studies

Clearly, examination of the published literature on tooth brushing in critically ill patients indicates that additional studies are needed. First, a safety study that uses different types of oral interventions, such as powered toothbrushes, needs to be designed to assess critical care patients' outcomes after tooth brushing. Hypotension and bacteremias, among other clinical signs and symptoms, should be included as outcomes of this safety study. After evidence to support the safety of tooth brushing in critically ill patients is obtained, a large, multicenter, randomized control study should be designed. That study should be powered to detect a small to moderate effect of tooth brushing as it affects VAP. The definition that will be used for VAP should be clear and well defined across study centers. Another outcome measure might include the bacterial composition of the oral microbiome.

Strict adherence to the research protocol is important. As mentioned, many of the oral care studies either did not report compliance or did not measure it as part of the protocol. The compliance should be reported and documented as part of the clinical protocol. If compliance decreases to below a predetermined limit, action should be instituted to correct it. The best-case scenario would be to have critical care nurses who have been trained by dental hygienists who are part of the research team provide the oral care.

Recommendations for Practice

The American Association of Critical-Care Nurses issued a practice alert for oral care that was placed on the organization's Web site in August 2006 and updated the next year.[14] Every critical care unit should have an oral care procedure that outlines frequent oral assessments, suctioning, and providing moisture to the lips and oral mucosa to prevent breakdown of these tissues. When a patient is admitted to a critical care unit, an oral history should be collected because gingivitis and periodontitis increase the risk of bacteremias.[5,41] Caries and poor oral health should be noted. An oral assessment tool that is appropriate for critically ill patients and easy for nurses to use must be developed and tested for reliability and validity. The practice alert is correct in stating that the data to support tooth brushing in critical care patients is limited at this time.

Summary

Tooth brushing may be an important intervention in the prevention of VAP. The importance of tooth brushing cannot be determined from a review of the current evidence. Nurses need to know if tooth brushing is safe and need to know that it does not initiate bacteremias and shock in critically ill patients. Nurses need to know what instruments to use to remove plaque from the teeth effectively and efficiently. Finally, critical care nurses need to know how often to perform this important intervention and how to assess whether plaque removal is successful.

> The importance of tooth brushing cannot be determined from this review of the evidence.

The pathogenesis of VAP is associated with the oral cavity, as demonstrated by the numerous studies in which decontamination of the oral cavity was associated with a decreased incidence of VAP.[37,42,43] However, it appears that attention to the study details, including protocol compliance, a clear yet concise definition of VAP, and control of confounding variables, will assist in designing a valid trial. Then, future researchers will be able to determine the risk versus benefit ratio of tooth brushing in critically ill patients. After these additional clinical studies, if appropriate, tooth brushing can be recommended as a safe, effective measure to prevent VAP.

FINANCIAL DISCLOSURES
None reported.

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