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**Electric vs. Manual Tooth Brushing among Neuroscience ICU Patients:
Is it Safe?**

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Abstract

Background: Poor oral hygiene has been associated with ventilator-acquired pneumonia. Yet providing oral care for intubated patients is problematic. Furthermore, concerns that oral care could raise intracranial pressure (ICP) may cause nurses to use foam swabs to provide oral hygiene rather than tooth brushing as recommended by the American Association of Critical Care Nurses. Evidence is needed to support the safety of toothbrushing during oral care. We therefore evaluated ICP and cerebral perfusion pressure (CPP) during oral care with a manual or electric toothbrush in intubated patients in a neuroscience intensive care unit (ICU).

Methods: As part of a larger 2-year, prospective, randomized clinical trial, 47 adult neuroscience ICU patients with an ICP monitor received oral care with a manual or electric toothbrush. ICP and CPP were recorded before, during, and after oral care over the first 72 hours of admission.

Results: Groups did not differ significantly in age, gender, or severity of injury. Of 807 ICP and CPP measurements obtained before, during, and after oral care, there were no significant differences in ICP ($P = 0.72$) or CPP ($P = 0.68$) between toothbrush methods. Analysis of pooled data from both groups revealed a significant difference across the three time points (Wilks' lambda, 12.56; $P < 0.001$; partial η^2 , 0.36). ICP increased significantly (mean difference, 1.7 mm Hg) from before to during oral care ($P = 0.001$) and decreased significantly (mean difference, 2.1 mm Hg) from during to after oral care ($P < 0.001$).

Conclusions: In the absence of preexisting intracranial hypertension during oral care, tooth brushing, regardless of method, was safely performed in intubated neuroscience ICU patients.

Trial Registration:

Clinicaltrials.gov, [Effects of Oral Care in the Neuroscience ICU; NCT00518752](https://clinicaltrials.gov/ct2/show/study/NCT00518752);
<http://clinicaltrials.gov/ct2/show/NCT00518752?term=oral+care+and+pneumonia&rank=4>

In the setting of an acute neurological injury, patients may respond to invasive procedures with increases in intracranial pressure (ICP), decreases in cerebral perfusion pressure (CPP), or both.¹ During the initial 72 hours after injury, cerebral edema evolves and can result in further neuronal deterioration.^{2,3} To prevent secondary injury in such patients, staff must be attentive to trends in ICP and their patients' responses to bedside care, which can include agitation and undesirable fluctuations in blood pressure and tissue perfusion. The resulting intracranial hemodynamic decompensation may exacerbate increased ICP and cause further neurological deterioration.

Foam swabs are often used to provide oral care due to their ease of use, convenience, and perceived effectiveness.⁴ Although tooth brushing is a fundamental component of bedside care, its safety in terms of intracranial dynamics, including different methods of tooth brushing, has not been thoroughly investigated. Tooth brushing can be performed with a manual or electric toothbrush, but which method is most effective in promoting oral hygiene and possibly reducing ventilator-acquired pneumonia (VAP) is unknown. Furthermore, which method is most safely tolerated by patients with a cerebral injury has not been established. Electric toothbrushes are best at removing dental plaque,⁵⁻⁷ but their use could overstimulate critically ill patients and therefore be detrimental, especially for patients with compromised intracranial dynamics.

The provision of oral hygiene is essential because of the relationship between pathogenic oral bacteria and the subsequent development of VAP.⁸⁻¹⁰ The American Association of Critical-Care Nurses has recommended tooth brushing twice daily with a pediatric toothbrush,¹¹ but clinical evidence that such interventions are well tolerated by patients is lacking. Early studies reported transient but significant increases in ICP of 3–10 mm Hg during unspecified oral care.^{12,13} In contrast, a recent exploratory study

suggested that oral care does not appear to affect ICP negatively.¹⁴ The scant conflicting evidence motivated this study to determine the safety of tooth brushing in intubated patients with acute neurological injuries by measuring the effects of intervention on intracranial dynamics..

Methods

This study was a planned interim safety analysis as part of a larger randomized controlled trial (RCT) comparing the effects of two oral care protocols on oral health and VAP in patients in a neuroscience intensive care unit (ICU). The study was approved by the Institutional Review Board of St. Joseph's Hospital and Medical Center, Phoenix, Arizona and was conducted in accordance with the Helsinki Declaration of 1975. Informed consent was obtained from each patient's next-of-kin. The study was registered at ClinicalTrials.gov (NCT 00518752).

Sample and setting

All adult patients aged 18 and older admitted to the neuroscience ICU between August 2007 and August 2009 at a tertiary medical center in the southwestern United States and intubated within 24 hours of admission were eligible for inclusion in the study. For this report, however, only patients with an external ventricular drain (EVD) in place for ICP monitoring with the position of the drain verified by postprocedural computerized tomography were included. Exclusion criteria were pregnancy, an edentulous state, facial fractures or trauma affecting the oral cavity, unstable cervical fractures, an anticipated extubation within 24 hours, or a grim prognosis.

A computer-generated randomization list maintained separately from enrollment forms to prevent manipulation of group assignment was used to allot patients to receive

oral care with either a manual or electric toothbrush. The randomization list was available only to the principle investigator and research assistants. Although the nurses administering oral care could not be blinded to the type of treatment delivered, individuals who obtained informed consent and assigned patients to treatment groups were not involved in the patients' oral care.

Procedure

Oral care kits, containing a copy of the assigned oral care protocol, designated toothbrush, and oral hygiene supplies, were placed in the patient's room. The control method of oral care consisted of tooth brushing with a manual pediatric toothbrush. Patients randomized to the alternative method underwent tooth brushing with an electric toothbrush (Oral B Vitality toothbrush, Newark, New Jersey, USA). Regardless of method, teeth were to be brushed for 2 minutes twice daily, once during the day shift and once during the night shift. For both methods, a wall-mounted digital clock was set for 2 minutes at the beginning of the oral care procedure. Patients in both groups had their mouths swabbed, and lubricant was applied to their lips and oral mucosa every 2 to 4 hours as needed.

All bedside nurses were instructed in both oral care methods and in how to record ICP and CPP values. If ICP exceeded 20 mm Hg or CPP decreased to less than 70 mm Hg during or after oral care for more than 5 minutes, the nursing staff recorded the change. Bedside nurses were also taught how to document the changes in ICP and CPP during oral care and any necessary nursing interventions. Daily rounds made by research assistants verified that nurses understood the protocol and were correctly completing bedside oral care records and restocking oral care supplies.

If a patient's EVD was ordered open to drainage, the drain remained open during episodes of oral care, but the registered nurse closed the drain midway during the procedure to monitor and record the patient's ICP. If a patient's EVD was ordered closed and sustained elevations of ICP above 20 mm Hg developed, cerebrospinal fluid was drained and the volume was recorded. Additional nursing interventions related to oral care, such as repositioning the head and administering sedation, analgesics, or diuretics, were instituted as needed. Nurses exercised independent judgment and recorded if oral care was withheld or aborted when a patient had increased ICP, when a patient was deemed too unstable, or when a patient was undergoing a procedure outside the neuroscience ICU.

Data collection

The Glasgow Coma Scale (GCS) score was used at enrollment as a global indicator of neurological impairment. Mean ICP and CPP values were recorded by the bedside nurse 30 minutes before, during, and 30 minutes after the teeth were brushed. The ICP and CPP signals were acquired from the bedside computerized system (Philips Intelliview NP 5, Irvine, CA, USA), which continuously displayed analog wave forms and digital values. All patients had arterial line measurements for blood pressure monitoring with continuous analog and digital display on the bedside monitor.

Data analysis

All data were analyzed with SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). The significance level was set at 0.05 (two-tailed). Descriptive statistics were used to summarize sample characteristics; percentages were calculated for gender, diagnosis,

admission GCS score, and nursing interventions. The means and standard deviations (SD) for age, ICP, and CPP were calculated for patients in both treatment groups. Only patients with ICP and CPP values recorded during times of tooth brushing were included in these analyses.

Repeated measures analysis of variance (ANOVA) was used to evaluate any differences in ICP and CPP values (dependent variables) during the first 72 hours after admission (time points as independent variables). The change in mean ICP and CPP (dependent variables) 30 minutes before, during, and 30 minutes after oral care (independent variables) was then analyzed using repeated measures ANOVA, with group assignment (manual or electric toothbrush) as an independent covariate. Data were checked regarding the underlying assumption of compound symmetry, which was met. Wilks' lambda was used as the multivariate ANOVA test statistics¹⁵. Bonferroni adjustment was made for multiple comparisons.¹⁶ The effect size (partial eta-squared for overall differences and r for paired differences)¹⁷ and precision (95% confidence interval) was calculated for the mean differences in ICP and CPP from before to during oral care, before to after oral care, and during to after oral care.

Results

Among the 98 patients assessed for eligibility, 47 patients with ICP monitoring were analyzed (Fig. 1). There were no significant differences in age, gender, diagnosis, or severity of injury between the two groups (Table 1). During the initial 72 hours after admission to the neuroscience ICU, all patients were mechanically ventilated. Continuous intravenous sedation was administered for 70% of patients on enrollment day with 60% sedated Days 1 through 3. Narcotics were routinely administered in 90% of

patients on the day of enrollment, and an average of 77% of patients received narcotics on Days 1 through 3 (data not shown). There were 807 ICP and CPP measurements related to the oral care procedure, with a mean of 17 measurements per patient during the first 72 hours after admission. Altogether, 57 (7%) ICP and CPP measurements were missing at random because the patient was undergoing surgery or the nurses failed to complete the form.

During the first 72 hours, oral care was provided 127 (total possible = 160; 79%) and 161 (total possible = 216; 75%) times, respectively, for patients in the electric ($n = 20$) and manual ($n = 27$) toothbrush groups. ICP or CPP values did not differ across the first 72 hours after admission, either 30 minutes before (ICP: Wilks' $\lambda = 0.07$, $P < 0.43$; CPP: Wilks' $\lambda = 76.31$, $P < 0.09$), during (ICP: Wilks' $\lambda = 0.49$, $P < 0.79$; CPP: Wilks' $\lambda = 0.10$, $P < 0.97$), or 30 minutes after oral care (ICP: Wilks' $\lambda = 0.57$, $P < 0.74$; CPP: Wilks' $\lambda = 0.06$, $P < 0.99$).

Mean (SD) ICP values for the electric toothbrush method ($n = 20$ patients) were 10.9 (7.5), 12.8 (8.2), and 10.5 (5.3) mm Hg 30 minutes before, during, and after oral care, respectively ($n = 352$ ICP recordings; total possible 381, Fig. 2). Corresponding mean ICP values for the manual toothbrush ($n = 27$ patients) were 10.7 (4.3), 12.3 (4.5), and 10.3 (4.5) mm Hg, respectively ($n = 455$ ICP recordings; total possible 483, Fig. 2). ICP values did not differ significantly between toothbrush methods ($P = 0.86$). Analysis of pooled data from both groups revealed a significant difference across the three time points (Wilks' $\lambda = 12.56$; $P < 0.001$; partial eta-squared, 0.36). ICP increased significantly with a mean difference of 1.7 mm Hg between 30 minutes before and during oral care ($P = 0.001$), followed by a significant mean decrease of 2.2 mm Hg in ICP

differences from during to 30 minutes after oral care ($P < 0.001$). Mean ICP values 30 minutes before and 30 minutes after oral care did not differ ($P = 0.72$, Table 2).

Mean (SD) CPP values for the electric toothbrush method were 74.0 (7.1), 73.5 (7.7), and 73.6 (5.3) mm Hg at 30 minutes before, during, and after oral care, respectively. Corresponding values for the manual toothbrush were 75.2 (9.3), 74.5 (11.5), and 74.7 (11.5) mm Hg. CPP values did not differ between toothbrush methods ($P = 0.68$) or among readings collected 30 minutes before, during, and after oral care (Table 2). No significant differences between groups were noted in total nursing interventions provided before, during, or after oral care (data not shown).

Four patients had 14 instances of $ICP \geq 20$ mm Hg before scheduled oral care. In 10 of the 14 instances, the nurse did not perform oral care. The remaining four instances of increased ICP before oral care occurred twice in two patients (one in each group) with subsequent documentation of oral care. In the first case, a patient in the electric toothbrush group had ICP values of 41, 38, and 17 mm Hg and of 42, 42, and 38 mm Hg, respectively, documented before, during, and after two respective instances of oral care. Additional intravenous sedation was provided at each time point during each provision of oral care. In the second case, a patient in the manual toothbrush group had recorded ICP values of 22, 18, and 18 mm Hg and of 25, 20, and 18 mm Hg at the three time points. No nursing interventions were recorded at any time point during either occasion of oral care for this patient. The CPP values for both patients remained above 60 mm Hg at all time points.

Discussion

To our knowledge this study represents the largest series of neuroscience ICU patients yet evaluated in an RCT for changes in ICP and CPP associated with oral care. Unfortunately, scant data have been published on changes in ICP and CPP related to a nursing intervention of this kind. Although tooth brushing has been deemed best for oral care, the literature reports contrary nursing practice,^{4, 18} or nurses consider it problematic for intubated patients.¹⁹ This RCT therefore offers a unique perspective on intracranial stability during manual and electrical tooth brushing in 47 intubated neuroscience ICU patients based on serial recordings of ICP and CPP.

This analysis of intracranial hemodynamics was an interim analysis as part of the larger RCT investigating oral health and the development of VAP (which will be reported separately). As such, we analyzed the effect of type of oral care on ICP and CPP. The observed significant differences were modest and not clinically relevant. In the absence of intracranial hypertension at the time of oral care, tooth brushing was performed safely without clinically significant increases in ICP or decreases in CPP, regardless of toothbrush method. While the mean increase in ICP values was statistically significant during oral care, the elevation of 1.7 mm Hg was not a clinically significant change. That CPP remained constant, regardless of toothbrushing method, further supports the conclusion that the change in ICP was not clinically relevant. From the perspective of safe ICU practice, the data reported here support tooth brushing for intubated neuroscience ICU patients. However, the most effective method, electric versus manual, in terms of oral status requires further investigation.

The findings, which apply only to patients with ICP values within a normal range as most patients in this study had during and after oral care, suggest that

oral care was safely tolerated. In fact, ICP decreased after oral care an average of 2 mm Hg 30 minutes after oral care. Transient elevations in ICP, lasting less than 5 minutes, occurred in fewer than 7% of patients in either group. In a singular episode, one patient in the manual toothbrush group required drainage of cerebrospinal fluid because of a transient elevation in ICP. Overall, the two methods were well tolerated.

ICP is dynamic and normally fluctuates in response to care. In a descriptive study by Snyder,²⁰ basic nursing care activities resulted in a mean increase in ICP of 8-12 mm Hg that persisted 3 to 5 minutes in nine head-injured patients whose ICP was measured by a subarachnoid bolt. However, oral hygiene was not specifically cited in that study, and the type of nursing interventions performed are unclear. In a nonrandomized trial, 1248 patients in a medical-surgical ICU received oral care with a toothbrush and povidone-iodine swab.²¹ Neuroscience patients accounted for 3% of the study population, but patients undergoing ICP monitoring were not identified. In the one study in which ICP was recorded during unspecified oral care (tooth brushing or swabs), ICP was stable in 879 recordings among patients with ICP values less than 20 mm Hg. In patients whose ICP was greater than 20 mm Hg, no trend of increasing ICP was detected.¹⁴ Thus, the findings of the current study are consistent with those of earlier research suggesting that tooth brushing, electric or manual, is safe.

That both methods of brushing were safely tolerated among neuroscience ICU patients warrants further investigation to establish which method is the most effective in promoting and maintaining oral health in neuroscience ICU patients. A study examining the difference between oral care with chlorhexidine vs. oral care with an electric toothbrush and chlorhexidine identified no reduction of VAP.²² The study was limited by a small sample size, however, and no measures of overall oral health were obtained.

The current data were primarily generated in patients with normal ICP values during oral care. Consequently, the observations cannot be extrapolated to guide oral care for patients with increased ICP. Additional research is needed to examine the effects of oral care on patients with ICP >20 mm Hg. Patients enrolled in the study had clinical conditions that warranted ICP monitoring and their first 72 hours of hospitalization is a period during which increased ICP may become a serious clinical problem.

The study had several limitations. First, data are lacking on patients' 24-hour mean ICP and on whether patients had recently undergone a therapeutic intervention to reduce ICP before initiation of oral care. Another limitation of this study is that the main diagnostic category of the enrolled patients was stroke. It is unclear if the ICP and CPP results would have been similar in patients with other neurological diagnoses such as traumatic brain injury. While cerebral autoregulation is impaired among patients with a traumatic brain injury,²³ such derangements have also been described in patients with various intracranial vascular abnormalities and in patients with cerebral vasoconstriction or vasodilation.²⁴ Additional monitoring of brain tissue oxygenation may prove useful for detecting possible regional changes in brain tissue perfusion during oral care. Finally, nurses' bias toward method of oral care and the difficulty of performing the task in intubated patients may have influenced the values of ICP and CPP.

The provision of oral hygiene to promote oral cleanliness must be weighed against the possible deleterious physiological effects of such stimuli. Furthermore, it is challenging for the nursing staff to give oral care to intubated patients because access to their mouth is hampered by the presence of the endotracheal tube and bite blocks. In the midst of advanced intracranial monitoring techniques, one cannot overlook the fundamentals of oral care and its possible impact on ICP and CPP in this fragile

population. Further research is required to establish the safety of tooth brushing among patients with elevated ICP and to determine if different tooth brushing methods differentially affect oral cleanliness and the incidence of VAP among ICU patients. However, the nonsignificant clinical changes in ICP and the stability of CPP values in this study underscore the feasibility of tooth brushing among patients with ICP less than 20 mm Hg. These findings can be used to dispel concerns among nurses that intubated patients cannot tolerate oral care. Notwithstanding, further evidenced-based research is needed to guide development of best practices for optimal oral care for critically ill, intubated patients with decreased intracranial compliance.

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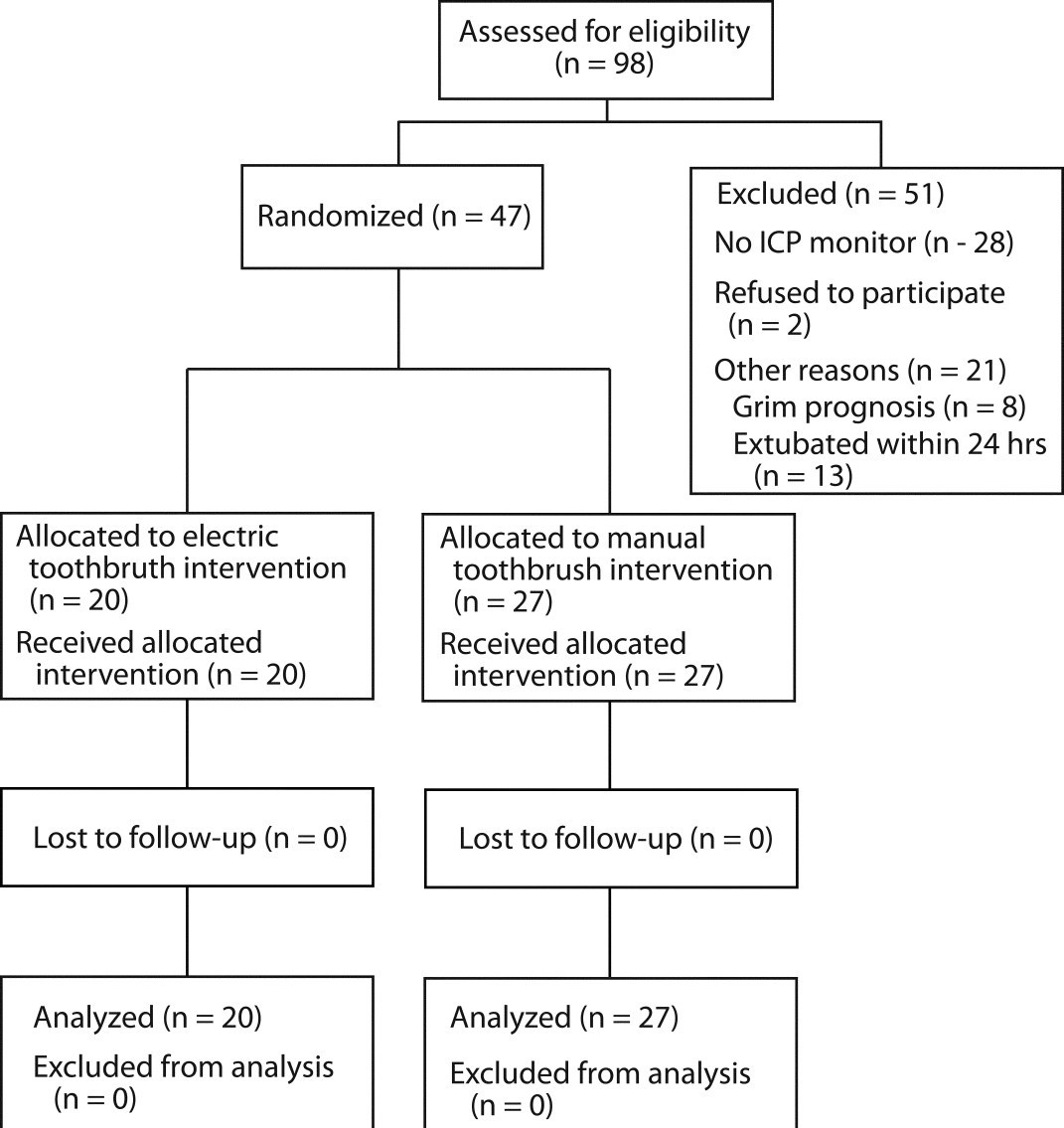
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Figure Legends

Figure 1. CONSORT flow diagram of participants for toothbrush method. *Used with permission from Barrow Neurological Institute.*

Figure 2. Mean (95% CI) ICP changes from enrollment through 72 hours. N=47 patients (electric = 127 episodes of oral care; manual = 161 episodes of oral care). *Used with permission from Barrow Neurological Institute.*



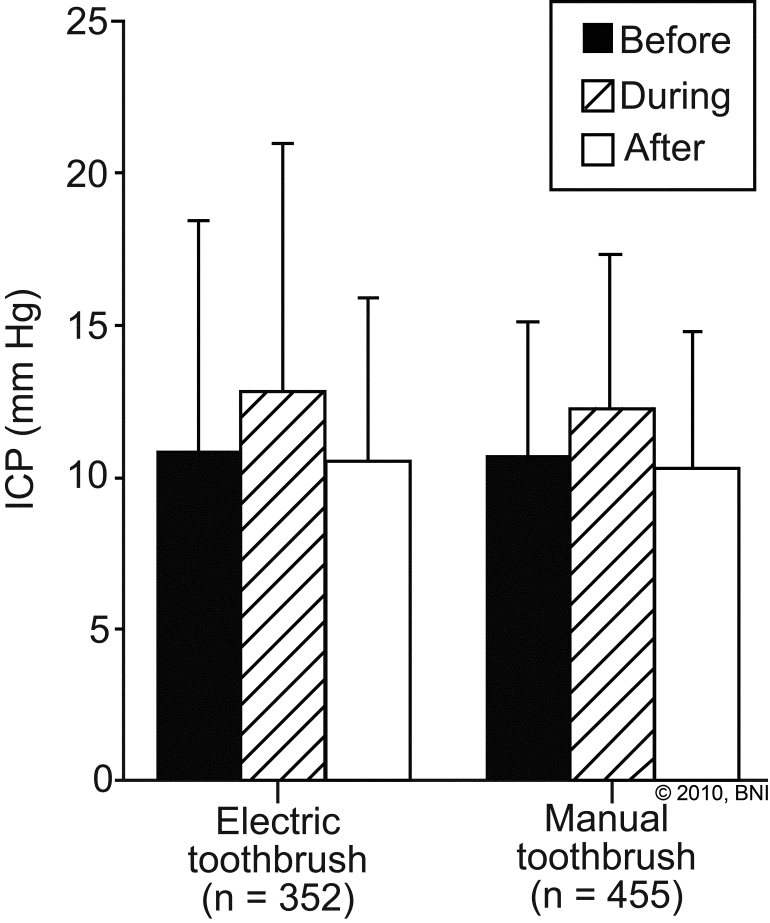


Table 1. Clinical Summary of Patients at Admission

Variable	Manual toothbrush n=27	Electric toothbrush n=20	<i>P</i> value
Age (years), mean (SD; min–max)	47 (18; 18–78)	51 (19; 19–79)	0.47 ^c
<i>Gender</i>			0.77 ^d
Male n (%)	11 (40.7)	9 (45.0)	
Female n (%)	16 (59.3)	11 (55.0)	
<i>Admission GCS^a</i>			0.40 ^e
Severe (sum score 3–8) n (%)	21 (77.8)	15 (75)	
Moderate (sum score 9–12)	6 (22.3)	5 (25)	
<i>Admission diagnosis</i>			0.28 ^e
Stroke	23 (85)	14 (70)	
Other ^b	4 (15)	6 (30)	

^a Glasgow Coma Scale: possible score range 3–15 (15 = no impairment of consciousness)

^b Other = traumatic brain injury, brain tumor

^c Independent t-test; ^d Chi-square test; ^e Fisher's exact test

Table 2. Mean changes in ICP and CPP in 47 Patients Enrolled for 72 hours^a

Variable	Mean difference (mm Hg)	95% CI of mean difference (mm Hg) ^b	<i>P</i> value ^b
<i>ICP</i>			
30 minutes before to during OC	1.71	-2.81, -0.61	0.001
During to 30 minutes after OC	-2.18 ^c	1.08, 3.28	<0.001
30 minutes before to 30 minutes after OC	0.47	-1.45, 0.51	0.72
<i>CPP</i>			
30 minutes before to during OC	0.60	-1.07, 2.27	1.00
During to 30 minutes after OC	-0.14	-1.82, 1.55	1.00
30 minutes before to 30 minutes after OC	-0.46	-1.53, 2.45	1.00

OC = oral care

^a 807 observations^b Bonferroni adjustment for multiple comparisons^c Negative value reflects decrease in ICP/ CPP