Dental Suction Interference and Acoustic Respiratory Monitoring

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Objective: Previous studies have reported that the noise generated by dental equipment can interfere with the auscultation of respiratory sounds during sedation. Therefore, this study aimed to identify whether positing the acoustic sensor on the chest or cervical position would be least susceptible to interference from dental suction device noise, a prominent noise noted during respiratory sound monitoring during dental sedation.

Methods: This prospective cohort study was conducted with 30 students. Sound intensity (dB) and frequency (kHz) levels from the dental suction were recorded from the cervical and chest regions under both oral and nasal breathing conditions and analyzed.

Results: The mean intensity of dental suction sounds was significantly lower in the chest region compared with the cervical region, regardless of the breathing condition ($P < .001$). Furthermore, in the chest region, the mean sound frequency during oral breathing was significantly lower than that during nasal breathing ($P < .01$).

Conclusions: Our study suggests that monitoring respiratory sounds in the chest region can significantly reduce interference from noise generated by dental suction devices compared with monitoring at the cervical region.

Key Words: Sound monitoring; Deep sedation; Dental treatment; Respiratory monitoring; Sedation.

Although minimal and moderate sedation is widely used during dental treatment, deeper levels (eg, deep sedation and general anesthesia) are often necessary for patients exhibiting difficult or combative behaviors. In such cases, the risk of respiratory issues (eg, airway obstruction and apnea) is high, and early identification and appropriate management depend heavily upon reliable respiratory monitoring for the prevention of serious respiratory complications.[1–6]

Practice guidelines published by the American Society of Anesthesiologists and other notable organizations recommend auscultation of breath sounds and observation of the thorax in addition to capnography and pulse oximetry (SpO_2) monitoring during sedation and general anesthesia.[1–4] However, traditional analog auscultation and observation are subjective and require extensive clinical experience, making quantitative evaluation difficult.[6] Additionally, the operative field and the airway overlap in dental practice, and there is often substantial noise generated from the dental suction and other equipment, all of which can be major obstacles to effective sound monitoring.[7–11]

To date, no studies have compared the effects different anatomic sampling sites or breathing routes may have on noise interference produced by the dental suction. This study aimed to evaluate sounds transmitted to the cervical and chest regions during oral versus nasal breathing conditions to determine which anatomic site is less impacted by the dental suction during dental sedations. We hypothesized that distancing the acoustic sensor from the source of background noise could reduce interference. The primary outcome of this study was to compare the intensity of dental suction sounds measured at the cervical and chest

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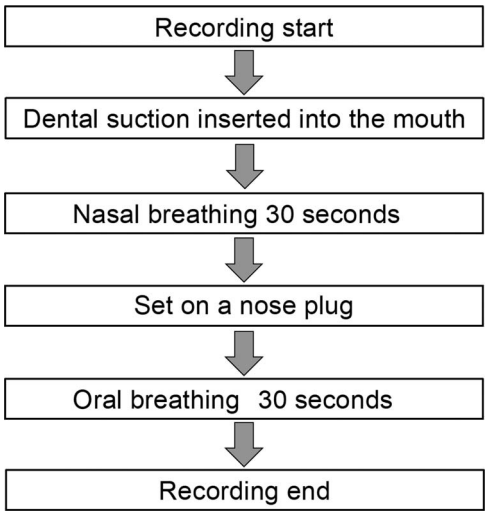
Figure 1. Study Protocol



The protocol used in the volunteer study to record the sounds during 30 seconds of nasal or oral breathing patterns.

regions during oral and nasal breathing conditions. Secondary outcomes included comparing the frequency of dental suction sounds as measured at these 2 locations during oral and nasal breathing conditions.

METHODS

This prospective cohort study was approved by the Certified Review Board of Hiroshima University (approval numbers: E-1500 and E-1500-1) and registered for clinical research (UMIN ID: 000040847). All procedures adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all study participants.

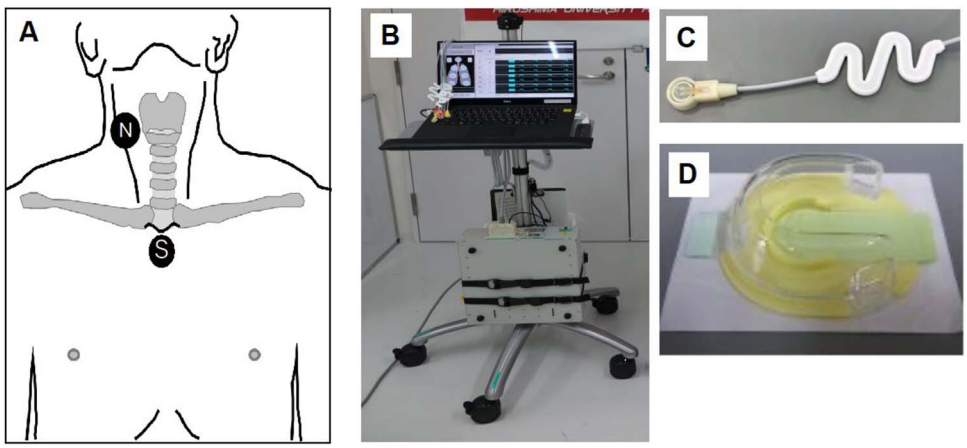
Students from the Faculty of Dentistry at our institution were invited to volunteer as study participants. Individuals with serious underlying conditions and those unable to tolerate nasal breathing excluded from participating.

Acoustic sensors were placed on the anterior cervical and anterior chest regions to record suction sounds for 30 seconds while participants breathed either nasally or orally (Figure 1). A nose plug was used to replicate oral breathing conditions during that period. An original continuous respiratory sound monitoring system was used to collect dental suction sounds for further analysis of sound intensity and frequency. The respiratory sound monitoring system used in the study consisted of a prototype sensor with a soundproofing cover and a control unit with a collection frequency band of 20 to 23 kHz. Two sensors were placed using adhesive gel; one affixed to the right side of the anterior cervical region and another affixed inferior to the suprasternal notch (N and S, respectively; Figure 2).

The collection of sound recordings was exported as ".wav" files; the sampling frequency was 44.1 kHz, and the quantization bit rate was 16 bits. The sound data were analyzed using Adobe Audition (Adobe) and statistically analyzed using SPSS for Mac (version 25.0; IBM Corp). The intensity (dB) and frequency (kHz) sound data, presented as mean (SD), were analyzed using Student *t* test to assess for differences based on positioning of the acoustic sensors and breathing conditions. Statistical significance was set at $P < .05$.

We performed an a priori power analysis using G*Power (version 3.1.9.6; University of Düsseldorf) software to determine the sample size based on a previous investigation of lung disease using an electronic stethoscope and acoustic analysis published by our research group.[12] The minimum difference and SD that we considered were 0.08 and 0.06, respectively. Using an alpha of .05, a power of

Figure 2. The Acoustic Respiratory Sound Monitoring System



(A) Sensor attachment locations. (N, cervical sensor location; S, chest sensor location). (B) Photograph of the entire system. (C) Sensor. (D) Adhesive gel (equipped with a soundproofing cover to reduce friction noise).

Table 1. Participant Demographics.

Gender, No., male/female	14/16
Age, mean (SD), years	23.1 (1.7)
Height, mean (SD), cm	163.9 (6.8)
Weight, mean (SD), kg	59.2 (16.9)

.80, and a dropout rate of 50%, we calculated that the study would require a total of 30 participants.

RESULTS

A total of 30 participants (14 males and 16 females) were enrolled, and no participants were excluded. The mean age, height, and weight of the participants were 23.1 (1.7) years, 163.9 (6.8) cm, and 59.2 (16.9) kg, respectively (Table 1).

The dental suction sounds were significantly louder or higher in intensity during auscultation of the cervical region compared with the chest region regardless of nasal or oral breathing ($P = < .001$; Table 2). Furthermore, dental suction sounds were significantly louder during oral breathing versus nasal breathing when auscultating at the cervical region ($P = < .01$; Table 2). However, the difference in sound intensity during oral versus nasal breathing when auscultating at the chest region lacked significance (Table 2).

The only significant difference in the frequencies of dental suction sounds was found to be in the chest region during nasal versus oral breathing. Oral breathing (55.6 kHz) had a significantly increased low-frequency component compared with nasal breathing (61.6 kHz; $P < .01$; Table 2). All other differences in sound frequencies lacked statistical significance.

DISCUSSION

Airway management during deep sedation is often performed without intubation, and continuous assessment of the airway and respiratory function is paramount for the safe management of the patient. Dental sedation guidelines in Japan, Europe, and the United States recommend monitoring through capnography, which is the most reliable method with high sensitivity to apnea and airway obstruction, in addition to monitoring oxygenation status by pulse oximeter.[1–4] Furthermore, these guidelines recommend auscultation and direct observation of the patient; however, auscultation warrants a skilled practitioner.[1–2,6] In addition, environmental noise from treatment equipment and suction devices can influence dental sedation monitoring.[7–11]

The human audible range is typically between 20 Hz to 20 kHz. Sounds within this frequency range are generally perceivable. However, in environments with loud noises, the range for distinguishing specific sounds gets narrowed down, and this holds true for acoustic analyzers as well. As of 2023, one such sound monitoring device available is the Acoustic Respiration Rate (RRa; Masimo Corporation), a directional sensor with a built-in acoustic transducer that is attached to the neck and synchronizes the audiogram with a SpO_2 monitor attached to the fingertip.[11] However, the algorithm that detects breathing using only an audiogram cannot accurately observe the state of breathing in the presence of other noise.[11] Therefore, considering the inherently noisy environment of dental practice in general, the reduction of background noise is critical for accurate interpretation and analysis of respiratory sounds.

In this study, acoustic analysis of the noise generated by dental suction devices was performed in both areas, the cervical and chest, to clarify which of the 2 sensor placement sites was more ideal for monitoring respiratory sounds during dental sedation. The data from this study suggest that placing a sensor on the chest could be more useful for acoustic analysis during dental sedation as the dental suction sounds were less intense as compared with the cervical site. Therefore, respiratory sound monitoring in the chest region could reduce the impact of dental suction noise.

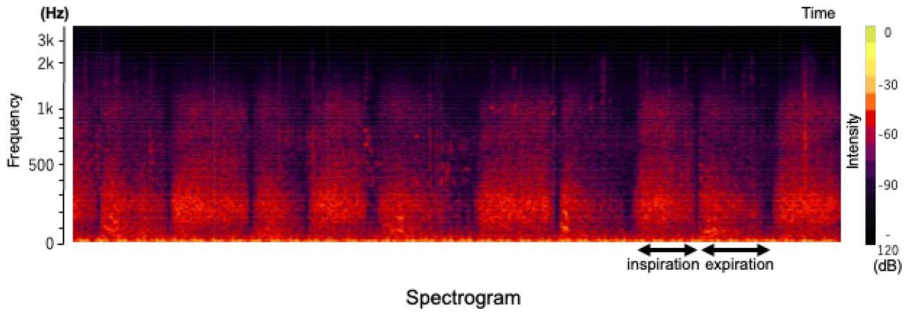
On the other hand, spectrograms (a 3-dimensional graph illustrating time, frequency, and intensity of sound components) in the chest region showed a high density of low-frequency components (Figure 3). However, noise from

Table 2. Sound Intensity and Frequency Data.

	Nasal breathing			*Oral breathing*		
	Cervical region	*Chest region*	*P value*	*Cervical region*	*Chest region*	*P* value
Intensity, mean (SD), dB	69.4 (3.5)	62.2 (3.5)	<.001	70.6 (3)	62.5 (3.3)	<.001
Frequency, mean (SD), kHz	58.1 (8)	61.6 (10)	0.14	57.5 (9.6)	55.6 (5.3)	0.3

	Cervical region			*Chest region*		
	Nasal breathing	*Oral breathing*	*P value*	*Nasal breathing*	*Oral breathing*	*P value*
Intensity, mean (SD), dB	69.4 (3.5)	70.6 (3)	<.001	62.2 (3.5)	62.5 (3.3)	0.29
Frequency, mean (SD), kHz	58.1 (8)	57.5 (9.6)	0.81	61.6 (10)	55.6 (5.3)	<.01

Figure 3. Spectrogram of Sound Recording



This spectrogram illustrates the recorded sounds auscultated from the chest region during oral breathing. The right color bar indicates sound intensity (dB).

dental suction in the chest region exhibited an increased low-frequency component under oral breathing conditions (Table 2). Therefore, it is suggested that noise countermeasures in the chest for low-frequency components may be necessary for acoustic respiratory monitoring during dental sedation.

Many patients without airway obstruction who receive dental sedation at optimal sedation levels can maintain nasal breathing, but if acute upper airway obstruction with symptoms such as snoring occurs during sedation, there may be an extension of the inspiratory cycle, resulting in oral breathing. In these cases, respiration cannot be detected by capnography with a nasal sampling tube.[13,14] In contrast, breath sound monitoring can be an effective way of respiratory monitoring in dental sedation because it allows respiratory quantification anywhere in the cervical and thoracic regions thorax and can complement the shortcomings of capnography.[15–18]

This study had several limitations. First, the sample size was small. However, the noise from the dental suction was identified, and the frequencies at which noise reduction should be performed during breath sound monitoring were clarified (Figure 3). Second, verification was limited to noise generated by the dental suction device. Other dental instruments, the material and shape of the cutting instrument edge, the type of cutting object, and environmental factors (including background music in the examination room and human conversation) may impact the interpretation and applicability of our findings.[19] Hence, further verification in an actual dental practice environment is recommended. Third, this study included healthy volunteers instead of actual patients receiving sedation. Furthermore, a nose plug was used to reproduce oral and nasal breathing conditions. There is a possibility that these special conditions may not accurately reproduce the anatomical and physiological conditions of the airway observed in sedated patients, particularly those under deep sedation or general anesthesia. Therefore, in the future, prospective studies targeting sedated patients should be conducted to comprehensively investigate this topic.

CONCLUSION

The findings of this study suggested that respiratory sound monitoring in the chest region should be preferred as opposed to the cervical region to reduce noise generated by the dental suction.

ACKNOWLEDGMENT

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