Scientific Article

Assessment of Noise Exposures in a Pediatric Dentistry Residency Clinic

Khaled Jadid, DDS[1] • Ulrich Klein, DMD, DDS, MS[2] • Deanna Meinke, PhD[3]

Abstract: ***Purpose:*** *In addition to sounds from dental equipment, pediatric dentists are exposed to noise produced by precooperative and/or noncooperative children. The purpose of this study was to evaluate the daily personal noise exposure of a pediatric dentistry resident while treating children in a teaching clinic to determine both comprehensive noise doses and peak noise occurrences as well as to assess the risk for noise-induced hearing loss.* ***Methods:*** *A noise dosimeter (Noise-Pro DLX) was used to measure the total personal noise exposure dose using the Occupational Safety and Health Administration (OSHA) Hearing Conservation Amendment criteria and the US National Institute for Occupational Safety and Health (NIOSH) occupational noise exposure revised criteria. Comprehensive noise doses for 31 days were obtained for a single resident.* ***Results:*** *OSHA and NIOSH-allowable limits were not exceeded during any one day in the study period. Noise levels during crying episodes, however, were higher than the reported noise levels of dental instruments and reached maximum levels of 112.9 dBA.* ***Conclusions:*** *Noise levels to which the pediatric dental resident was exposed fell below the Occupational Safety and Health Administration's and National Institute for Occupational Safety and Health's damage-risk thresholds for noise-induced hearing loss.* *(Pediatr Dent 2011;33:343-8) Received January 17, 2010 | Last Revision July 20, 2010 | Accepted August 9, 2010*

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Dentists are exposed to various sources of potentially hazardous noises in their work environment, which include dental instruments such as turbines, high-velocity suction, and laboratory equipment.[1,2] In addition to these sources, pediatric dentists are inherently subject to young, precooperative and/or noncooperative children's only means of expressing their fear and disagreement with dental treatment: crying and screaming. Very young children will cry even during routine exams and toothbrush prophylaxes. Other dental procedures such as tooth extractions are even more difficult for young children to cope with and will at times elicit substantial expression of displeasure despite adequate levels of local anesthesia. The acoustic significance of children screaming is that it may create high sound level spikes during short periods of time.

Repeated exposures to high-level noise for only minutes per day can have consequences that exceed the effects of longer exposure to lower continuous sound levels. When the cumulative daily noise exposure is composed of different sounds of various levels and durations, the combined effect must be considered rather than the individual sound level of each source. Terms and definitions related to this topic are summarized in Table 1.

According to the Occupational Safety and Health Administration's (**OSHA**) 29 CFR1910.95 occupational noise standard, repeated noise exposure at levels equal to or exceeding the permissible exposure limit (**PEL**) of 90 dBA time-weighted average (**TWA**) may cause a noise-induced hearing loss (**NIHL**).[3] NIHLs are typically high frequency in nature with a greater degree of hearing loss in the 3 to 6 kHz range, at least in the early stages.[4] High frequency hearing losses will negatively impact the ability to hear speech sounds and will contribute to communication difficulties, especially in listening situations with elevated background sound levels.[5]

The effects of noise can be categorized into auditory effects such as chronic NIHL and tinnitus, as well as nonauditory effects, such as interference with understanding speech, disrupted sleep, poor concentration, diminished morale, and task inefficiency. Specific to dentistry, the use of high-speed dental handpieces may contribute to an increase in heart rate and blood pressure.[6]

The hazardous effects of noise are dependent upon the intensity, duration, and spectral content of the sound and can be measured by noise dosimetry. The latter is based on the integration of the level and time characteristics of the sound exposures. Time is typically integrated using either a 5- or 3-dB exchange rate by halving or doubling the allowable exposure time dependent upon the intensity value change. Both OSHA 29 CFR 1910.95 and the National Institute for Occupational Safety and Health's (**NIOSH**) best practices (1998) specify the permissible or suggested levels of noise exposure for US workers.[7,8]

For OSHA, noise dose is determined using a 90 dBA criterion for the PEL and a 5 dB exchange rate. OSHA's PEL specifies that an 8-hour average exposure of 90 dBA is equivalent to a 100% dose. For every increase of 5 dB above the PEL,

[1]Dr. Jadid is a pediatric dentist in Dallas, Texas; [2]Dr. Klein is professor and chair, Department of Pediatric Dentistry, University of Colorado School of Dental Medicine and Children's Hospital Colorado, Aurora, Colo; and [3]Dr. Deanna Meinke is associate professor of Audiology and Speech-Language Sciences, University of Northern Colorado, Greeley, Colo.

Correspond with Dr. Jadid at k.jadid@yahoo.com

the allowable time is reduced by half; therefore, 95 dBA is permissible for 4 hours and 100 dBA for 2 hours, respectively.

For NIOSH (1998) purposes, a 3 dB exchange rate is utilized with a recommended exposure level (**REL**) of 85 dBA for an 8-hour period. Equivalent 100% noise doses can be attained for a 4-hour 88 dBA exposure, a 2-hour 91 dBA exposure, and a 1-hour 94 dBA exposure. In general, repeated exposures to sound levels above 85 dBA have the potential to contribute to NIHL and tinnitus.[9] Both the US Environmental Protection Agency (**EPA**) and World Health Organization (**WHO**) have suggested noise exposure guidelines for daily 24-hour periods that incorporate the risk of NIHL from both occupational and nonoccupational noise sources. These agencies reference a 70 dBA average time level (**L_{eq}**) for a 24-hour period or a 75 dBA L_{eq} for 8 hours.[10,11] The corresponding standard of the International Standards Organization from 1999 incorporates the 75 dBA L_{eq} for the 8-hour limit value, as well.[12]

Specific to the dental profession, a study on the effects of occupational ultrasonic noise exposure on the hearing of dental hygienists reported that ultrasonic scalers might contribute to a hearing loss at 3,000 Hz.[13] Another study on the spectral characteristics of sounds emitted by high-speed dental turbines concluded that, under any working conditions, high-speed dental air turbines emit high frequency spectral sounds that can potentially contribute to hearing loss.[14] Dentists using high-speed dental handpieces were found to have poorer hearing thresholds than physicians for the 4,000 Hz test frequency, with greater hearing loss noted for right-handed dentists.[15]

In dental schools, sound levels vary between 60 and 99 dBA, with the highest levels being observed in gypsum and prosthesis laboratories.[16] Higher sound levels were considered to be close to exceeding damage-risk criteria for NIHL. Working in an operative technique laboratory for 2 hours caused a temporary auditory threshold shift for second-year dental students, with some students experiencing some degree of reversible hearing loss 15 minutes after leaving the laboratory.[17] By contrast, others have not found any significant hearing loss in dentists associated with the use of high-speed dental instruments and concluded that noise levels in dental clinics are considered to be below the OSHA damage-risk limit for NIHL.[18-20]

Another publication reported the sound levels emitted by instruments commonly encountered in the dental clinic and laboratory.[21] The sound maxima recorded for amalgamators, ultrasonic scalers, high-speed handpieces with high-velocity suctions, high-volume suctions touching mucosa, and slow-speed headpieces were 68, 88, 75, 72, and 72 dBA, respectively. These values demonstrate that an ultrasonic scaler is the only instrument that emits noise levels greater than 85 dBA. Sound maxima measured in the dental laboratory were higher than those in the dental clinic, reaching 87 dBA for a sandblaster and 86 dBA for compressed air, a steam cleaner, and a stonecutter. Since the dental professional relies upon effective communication for patient instructions and support during procedures, elevated sound levels, although not considered hazardous to hearing, may create a communication interference.[22]

The potential impact of screaming children on the care providers' auditory system has not been given appropriate consideration in the literature, despite anecdotal reports by pediatric dentists stating that young and uncooperative children can produce significantly elevated sound levels.

The purposes of this study were to: compare typical noise exposures in a pediatric dental clinic to the Occupational Safety and Health Administration action level and permissible exposure limit, as well as the National Institute for

Table 1. GLOSSARY OF TERMS AND DEFINITIONS*

Term	Abbreviation	Definition
A-weighting		An electronic filtering system in a sound meter that allows the meter to largely ignore lower frequency sounds in a similar fashion to the way our ears do
Decibel, A -weighted	dBA	Unit of sound level; the weighted sound pressure level by the use of the A metering characteristics and weighting specified in ANSI specifications for sound level meter
Decibel sound pressure level	dB SPL	20 times $\log_{10}$ of the ratio of the sound pressure measured to the reference pressure of 20 μ-N/M^2. In equation form, SPL in units is expressed as SPL (dB)=20 log p/p_r.
Decibel	dB	A unit of sound pressure level
Hertz	Hz	Unit of measurement of frequency, numerically equal to cycles per seconds
Time-weighted average	TWA	The time-weighted average always averages the sampled sound over an 8-hour period
Average sound level	L_{avg}	Average sound level measured over the run time of the recording
Average time level	L_{eq}	The term LEQ is functionally the same as LAVG, except that it is only used when the exchange rate is set to 3dB and the threshold is set to none.
Dose	%	Related to the criterion level, a dose reading of 100% is the maximum allowable exposure to accumulated noise.
Maximum level	L_{max}	The highest sampled sound level during the instrument's run time allowing for the response that the unit is set for (fast or slow)
Exchange rate		An increment of decibels that requires the halving of exposure time, or a decrement of decibels that requires the doubling of exposure time
Threshold		Affects the L_{avg}, TWA, and dose measurement. All sound below the threshold is considered nonexisting noise for the averaging and integrating functions. The threshold does not affect measurements in the sound level mode.
Criterion level		The maximum allowable exposure to accumulated noise; it gives the conditions that result in 100% dose. It is typically set by a regulatory agency such as OSHA and is usually not applicable for community noise monitoring.

Occupational Safety and Health-recommended exposure limit; and measure the daily combined noise level that was produced by dental instruments and young children and to which one resident was exposed in a pediatric dentistry residency clinic.

Methods

A noise dosimeter (Noise-Pro DLX, from Quest Technologies, Oconomowoc, Wis) was used and programmed to measure the total personal noise exposure dose using the OSHA Hearing Conservation Amendment and NIOSH-recommended criteria. Over 6 weeks, dosimetry samples were obtained for 31 standard workdays of a pediatric dentistry resident in a hospital-based program, in a clinic that had only individual quiet operatories. During these days, the resident performed procedures that are typically done by pediatric dentists on a daily basis, such as new patient/recall exams, restorative treatment, procedural sedations, and associated laboratory work. This second-year resident was representative of all other care providers in the resident clinic. The schedules were relatively light (~10-12 patients per day) due to the clinical training environment and a difficult-to-manage patient population. A comprehensive noise dose, TWA, and average noise exposure levels (L_{avg}, L_{eq}) for each of these consecutive 31 days (only interrupted by weekends) were obtained, with an average recording time of 7.6 hours per day.

A noise dosimeter is a small portable device that clips to a wearer's belt and receives the sound level information from a small microphone that fastens to the garment close to the wearer's ear. It records and instantly performs calculations to evaluate all daily sound exposures and integrates these measurements over time, providing an average noise exposure reading for the entire sample period. QuestSuite Professional II software (Quest Technologies), which includes a noise dosimetry application, was used to analyze the recorded noise data.

For the daily noise measurements, the dosimeter microphone was attached to the pediatric dental resident's clothing in his hearing zone. OSHA defines the hearing zone as a sphere with a 2-foot diameter surrounding the head. For the right-handed resident, the microphone was attached on the left shoulder to have it represent the noise exposure for the ear closest to the noise source, and it remained in that position for the entire workday. At the end of each workday, the resident downloaded the daily noise exposure values to a computer. He was also responsible for keeping a daily exposure logbook with information about his clinical activities and specific encounters of noisy events (eg, at 10:15 a.m., screaming during a lap exam was observed). An audiologist reviewed the dosimeter data and workday logs with him and helped with interpretation of specific data points. Measurements that could not be reconciled with documented noisy episodes were excluded. The noise dosimeter was calibrated before and after each use, according to the manufacturer's instructions to ensure accurate results. It was preprogrammed to simultaneously collect the daily noise exposure measurements according to OSHA 29 CFR 1910.95 and NIOSH (1998) noise-sampling protocols, as summarized in Table 2.

Data analysis. Noise spikes that could not be matched with noisy activities in the noise exposure log were excluded from the analysis. The resulting daily summary statistics were: L_{max}, the maximum level, which reflects the highest value recorded using the slow meter response, A-weighted filter network; TWA, the time-weighted average sound over an 8-hour period; L_{avg} and L_{eq}, the average sound levels measured over the run time of the recording; and the noise dose, which represents the maximum allowable exposure to accumulated noise when compared to regulatory or best practice guidelines.

The slow response maxima were converted into a dichotomous variable based on whether or not they exceeded 90 dBA. Continuous equivalent 8-hour A-weighted sound levels (TWA) and daily averages (L_{avg}) for the time periods sampled were also converted into dichotomous variables to compare their values to the OSHA-allowable and NIOSH-recommended limits. The data were analyzed to determine the frequency of days during which maximum noise levels exceeded 90 dBA and whether daily noise doses exceeded the OSHA action level (**AL**), PEL, and/or NIOSH reference limits.

The numbers in Table 3 demonstrate the importance of using a noise dosimeter with an 80-dBA threshold to characterize a subject's noise exposure by showing hypothetical exposure scenarios to illustrate the relationship between the noise-sampling protocol relative to criterion level, threshold, and exchange rate. An instrument with a 90 dBA threshold will not integrate any noise below that level, and will, thus, give a readout of 0% even if the provider measured is actually being exposed to 89 dBA for 8 hours (equivalent to 87%

Table 2. NOISE DOSIMETER SAMPLING PROTOCOLS

Dosimeter parameters	Threshold (dBA)	Criterion level (dBA)	Exchange rate (dB)
OSHA (AL)	80	85	5
OSHA (PEL)	90	90	5
NIOSH (REL)	80	85	3

* Sources: Glossary of Terms at: "http://www.questtechnologies.com/Library.aspx" and "http://www.nonoise.org/library/diction/soundict.htm".

Table 3. HYPOTHETICAL NOISE EXPOSURE SCENARIOS AND THEIR CORRESPONDING NOISE DOSIMETER READ-OUT IN % OF MEASURED NOISE DOSE

Criterion level	Threshold (dBA)	Exchange rate (dB)	Exposure conditions in %			
			95 dBA for 8 hs	90 dBA for 8 hs	85 dBA for 8 hs	80 dBA for 8 hs
OSHA action level	80	5	200	100	50	25
OSHA permissible exposure limit	90	5	200	100	0	0
NIOSH recommended exposure level	80	3	1,000	317	100	32

Table 4. COMPARISON OF MEASURED AVERAGE NOISE LEVELS AND NOISE DOSES

Sampling paradigm	Slow max (dBA)	Time-weighted average (dBA)	Lavg/Leq (dBA)	Dose in %
OSHA action level	106.0	64.3	64.7/69.9	4
OSHA permissible exposure limit	106.0	56.8	57.5/69.9	2
NIOSH-recommended exposure level	106.0	75.2	75.4/75.4	17
Extrapolated average time level (0 dB threshold, 3 dB exchange rate, 85 dB criterion level)	106.0	76.5	76.8/76.8	21

of the allowable noise dose over any 8-hour period when referencing the OSHA PEL or 250% dose when referencing the NIOSH criterion).[3,7] The 90 dBA threshold for the PEL measures is designed to be used to evaluate the need for engineering or administrative noise control in the workplace, whereas the 80 dBA threshold is intended to characterize the noise exposure for purposes of hearing loss prevention program inclusion decisions.[3]

QuestSuite Professional II software permits the user to manipulate the noise samples post-hoc. This provides an opportunity to further assess the noise exposures without the regulatory limitations imposed by the threshold settings implemented by the preprogrammed OSHA and NIOSH sampling protocols. A subsequent data analysis includes an assessment of the noise exposures using a 0 dBA threshold and 3 dB exchange rate with an 85 dBA criterion in order to derive the average sound exposure over the sampling period (L_{eq}) and subsequent conversion to noise dose without regard to a predetermined threshold value.

Results

Sound level measurements. The average slow maximum sound level was 106 dBA, with a range between 94 and 112.9 dBA. These values will be consistent for all sampling paradigms because they exceed the dosimeter threshold values implemented for each sampling protocol. Isolated sound peak levels above 140 dB were occasionally recorded. Critical inspection of the time-history dosimetry records revealed that these isolated peak levels were random and could not be correlated with any particular acoustic event. Consequently, these instances were deemed to be an artifact attributed to accidental contact with the microphone and did not contribute significantly to the overall noise doses measured.[23]

Average sound levels of noise produced when children cried during lap exams, papoose board treatments, and during unsuccessful sedations, were 88.3, 90.1, and 86.3 dBA, respectively. The incidental maximum sound levels for the same procedures across all sampled days were 101.7, 98.6, and 98.1 dBA, respectively.

OSHA noise exposure criteria. On any particular day during the sample period, the OSHA AL and PEL were never exceeded. When sampled for OSHA AL, the noise doses ranged from approximately 1% to 14% and averaged 4%. As expected, noise doses were even lower for the OSHA PEL (~0-9%) due to the increased threshold level (90 dBA) used for noise sampling. The highest slow maximum level of 112.9 dBA does not violate the ceiling limits imposed by OSHA at 115 dBA. The minimal noise exposure values confound the absolute calculation of L_{avg} and TWA sound levels when the values fall below the measurement range of the instrument (70 dBA in this case). Therefore, reported L_{avg} and TWA's below 70 dBA may not be accurate when sampled according to the OSHA AL and PEL paradigm, but this is not of concern since sound levels below 70 dBA are assumed to not be hazardous to hearing.[11]

NIOSH-recommended exposure criteria. Sound level averages during the overall study period were 75.2 and 75.4 dBA for TWA and L_{avg}, respectively. These findings indicate that the NIOSH-recommended average exposure (85 dBA TWA) and dose limits (100%) were not exceeded during any one day during the study period. The average NIOSH daily noise doses recorded during the study ranged from approximately 1% to 79% and averaged approximately 17%. There was significant variability from day to day in the noise doses measured.

Comparison of noise exposures. A summary comparison of the average L_{max} sound levels, the measured TWAs, and noise doses as well as the average sound levels (L_{avg}/L_{eq}) recorded and calculated over the 31-day sample period are provided in Table 4. The extrapolated L_{eq} is representative of the average sound level over the sampling periods without reference to a specific sound level threshold value and, thus, is comparable to EPA and/or WHO noise exposure recommendations.

Discussion

Average noise exposures did not exceed a 100% dose during any one day of the 31-day study when referencing any of the 3-dosimeter sampling protocols. The highest average daily dose of 84% was recorded according to NIOSH criteria. This indicates that OSHA and NIOSH limits were not exceeded during any particular day during the study period. Temporary noise levels produced by crying children during lap exams, papoose board use, and sedation procedures, however, often exceeded 85 dBA and were variable in duration. The high-pitched sounds of children in the dental operatory routinely

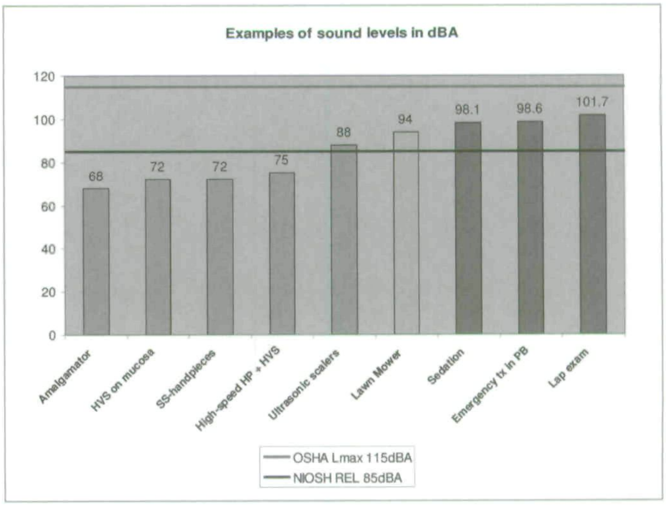

Figure 1. Examples of sound levels of dental instruments vs sounds produced by children.

reached maximum levels in excess of 98 dBA. These values are higher than the noise levels of the dental instruments, including an ultrasonic scaler that has been shown to emit 88 dBA of noise. Figure 1 provides a relative comparison of the measured maximum sound levels reported in previous publications with those measured in the current study. For additional context, the SPL emitted by a lawnmower is included.

This study used a portable dosimeter to measure the daily occupational noise exposure for a pediatric dentistry resident. This device is particularly suited for collecting noise exposure in situations where noise varies in duration and intensity and wearers are constantly moving or performing a variety of different activities during a typical workday. This study appears to be the first of its kind and, therefore, no other noise dosimetry data were available to compare the results to. Consequently, only comparisons to previously published isolated sound level measurements conducted for dental instruments could be made.

Average noise doses were calculated as approximately 4% using the OSHA AL, 2% using the PEL, and 17% when using the NIOSH-recommended REL protocols. Upon lowering the dosimeter threshold level to 0 and applying a 3-dB exchange rate, the average noise dose was approximately 21%. It should be noted that, during some days, the noise doses exceeded the 50% level of the NIOSH standard. This suggests that the potential for hazardous noise exposure exists, especially if working for extended shift durations or if a greater number of crying/screaming patients are encountered or if episodes of crying/screaming are extended. The L_{max} values never exceeded the OSHA ceiling limit of 115 dBA. Even moderate levels of noise, however, potentially contribute to a stress reaction, interfere with sleep, lower morale, reduce efficiency, create annoyance, interfere with concentration, or result in premature fatigue. Our data suggests that pediatric dentists may be at risk for incurring these nonauditory noise effects.

The post-hoc analysis revealed that approximately 13% (4 days) of the samples exceed 83 dBA L_{eq}, which is marginal for noise overexposure when one considers the ±2 dB instrumentation tolerances for noise dosimeters. Approximately 26% of the samples (12 days) exceeded 80 dBA L_{eq}, however, and approximately 61% of the samples (19 days) exceeded 75 dBA L_{eq}—a level that WHO suggests to be the maximum exposure level to avoid any risk of hearing impairment at 4,000 Hz.[11]

This study's results indicate that dentists who predominately treat children are exposed to overall higher noise levels than other dentists because children themselves produce significant sound in addition to the noise of dental instruments. As a consequence, when exposed for extended periods of time, these providers are potentially at a higher risk for auditory side effects—such as tinnitus, temporary hearing loss, and permanent hearing loss—associated with higher daily noise exposures resulting from the additive effects of instrument noise and noise produced by crying children.

Limitations of this study are the lower number of patients that were seen when compared to a private practice setting on any particular day due to the training environment and the fact that only one resident was measured. The study's results would be stronger if noise data from other dental settings such as general dentistry—obtained with the same methodology—were available for comparison, because other unknown sources of prolonged noise sources may exist there. We conducted an "exposure assessment," however, and not a sound level task analysis, and the daily sample included a higher proportion of emergency and special health care needs patients referred by other dental professionals. It will be important to further assess the risk for hearing loss in pediatric dentists by replicating the study in various practice settings and with more providers measured since generalizations beyond the pediatric training clinic to other practice settings are limited. Additionally, the amount of crying by the young patients varies and depends on the dentist's behavior management skills.

Education is the most effective method of raising awareness and reducing the risk for NIHL and tinnitus in dentists and auxiliary personnel.[24] Therefore, it is recommended that pediatric dental team members consider strategies for reducing noise exposure during their workday as well as after hours to minimize its adverse health effects from nonauditory responses that are acknowledged in the literature. Ideally, one would be able to reduce noise at the source, but in the case of pediatric patients this is not always a practical option. Other strategies to reduce noise exposures or diminish the impact of hazardous noise levels should be explored. Those may include alternating procedures that are expected to have higher noise levels with quieter ones to provide a rest period for the auditory system. In addition, maintaining good posture helps to keep an appropriate minimum distance from patients and dental instruments.

Finally, it is recommended to avoid noisy activities immediately after work to allow the auditory system to rest and recover. Noisy recreational/nonoccupational activities are considered voluntary exposure to noise or modifiable risk factors. Such noise exposures outside of the workplace contribute to the overall daily/lifetime noise dose and increase an individual's risk of NIHL and tinnitus. These activities include such pastimes as listening to loud music, attending loud sporting events, operating motorized vehicles such as motorcycles or snowmobiles, shooting firearms, or utilizing power tools without adequate hearing protection.

While a formal hearing loss and tinnitus prevention program for providers working in this residency clinic is legally not necessary, protective measures for auditory comfort and reduction of nonauditory noise effects—such as sleep disturbance, poor concentration, diminished morale, and work inefficiency—are recommended. Custom-made or other types of well-fitting hearing protectors can provide adequate attenuation in the dental office environment. Flat attenuation-hearing protectors or those incorporating electronic sound protection provide the additional benefit of hearing speech clearly while wearing hearing protection. Such devices help guard dental professionals from potentially hazardous noise levels produced by children and dental instruments while allowing them to communicate with the patient, which is a critical factor for successful behavior guidance methods in pediatric dentistry.

Seldom do individuals have the opportunity to measure their own day-to-day noise exposures at work or during recreational/social activities due to the expense and sophistication of traditional noise dosimeters. Relatively inexpensive consumer-oriented noise sampling instrumentation, however, has become available to dental professionals who are interested in monitoring their personal noise exposure. Daily/weekly readouts from these devices can enable dentists to modify work and/or recreational activities based on their daily noise exposure and encourage them to utilize hearing protection more frequently.

Conclusions

Based on this study's results, the following conclusions can be made:

1. For one pediatric dentistry resident wearing a noise dosimeter for 31 daily 8-hour clinic sessions in a residency clinic setting with quiet operatories only, noise limits allowed by the Occupational Safety and Health Administration and recommended by the National Institute for Occupational Safety and Health were not exceeded. Based on these data, a formal hearing loss prevention program for providers practicing in this specific setting is not legally required.
2. Sound levels of crying children can exceed those of dental instruments and may reach up to 112.9 dBA.

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