ORIGINAL RESEARCH

Assessment of noise levels of the equipments used in the dental teaching institution, Bangalore

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ABSTRACT

Context: In dental practical classes, the acoustic environment is characterized by high noise levels in relation to other teaching areas, due to the exaggerated noise produced by some of these devices and use of dental equipment by many users at the same time.
Aims: To measure, analyze and compare noise levels of equipments among dental learning areas under different working conditions and also to measure and compare noise levels between used and brand new handpieces under different working conditions.
Materials and Methods: Noise levels were measured and analyzed in different dental learning areas that included clinical, pre-clinical areas and laboratories selected as representatives of a variety of learning–teaching activities. The noise levels were determined using a precision noise level meter (CENTER® 325 IEC 651 TYPE II) with a microphone. The mean of the maxima was determined. The data were collected, tabulated, and statistically analyzed using *t* tests.
Results: The noise levels measured varied between 64 and 97 dB(A).The differences in sound levels when the equipment was merely turned on and during cutting operations and also between used and brand new equipments were recorded. The laboratory engines had the highest noise levels, whereas the noise levels in high-speed turbine handpieces and the low-speed contra angle handpieces were decreased.
Conclusion: The noise levels detected in this study are considered to be close to the limit of risk of hearing loss.

Received : 23-05-09
Review completed : 01-10-09
Accepted : 26-05-10

Key words: Noise level, dentistry, hearing loss, noise-induced, hearing conservation, occupational hazards

The acoustic environment of learning–teaching activities at a dental college is characterized by high noise levels in relation to other teaching areas, due to the exaggerated noise produced by the use of dental equipments by many users at the same time. Noise can have both auditory and non-auditory effects. It is well known that increased noise levels produce non-auditory effects like stress reactions with variations in heart rate, blood pressure, respiration, blood glucose and lipid levels, associated with psychical consequences like annoyance, mental fatigue and a reduction in efficiency, as well as auditory effects like noise-induced hearing loss (NIHL).[1]

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Access this article online
Quick Response Code:
Website: www.ijdr.in
DOI: 10.4103/0970-9290.87065

The aims of this study were to measure, analyze and compare noise levels of equipments among dental learning areas under different working conditions and also to measure and compare noise levels between used and brand new handpieces under different working conditions because of the issues discussed above.

MATERIALS AND METHODS

The noise levels of equipments used in laboratories, pre-clinical and clinical areas at the The Oxford Dental College and Hospital, Bangalore, Karnataka, were measured under different working conditions. The laboratories, pre-clinical and clinical areas will be henceforth referred to as dental learning areas in this study.

The sound levels were measured with a precision sound level meter (CENTER® 325 IEC 651 TYPE II) with a microphone in dental learning areas [Figure 1]. Sound levels are measured in A-weighted sound levels in decibels dB (A). The sound level is measured on the A scale, which was designed to mimic the response of the human ear. Considering that human hearing does not respond uniformly to all frequencies, sound measured in frequency bands may be A-weighted or adjusted to account for the approximate frequency dependence of human hearing. The result is a single number descriptor, the A-weighted sound level in decibels dB (A), where the letter A stands for the use of a specific type of low-pass electric filter.

In pre-clinical and clinical areas, the microphone was placed at ear level and at a distance of 6 inches from a main noise source to simulate the auditory position of the operator. The noise levels were measured over a 30-second interval and the average and maximum intensities were noted. The measurements were taken with the equipment only turned on (without cutting) and during cutting operations (such as cutting on tooth, typhodont, extracted tooth, acrylic, amalgam, composite). Ultrasonic scalers with or without suction pump and suction pumps running free and when they touch mucosa were measured for noise levels. Noise levels of brand new and used equipments were also measured.

Figure 1: Precision Noise Level Meter (CENTER® 325 IEC 651 TYPE II) with measuring tape

At the dental laboratories, the noise levels were measured in a similar way. The microphone was placed near the technician's ear to simulate the noise intensity reaching the eardrum, and another reading was taken 2 m away. This was to simulate the person within a 2-m radius of the operator who is also exposed to the same noise, although decreased in intensity, in a situation where multiple operators exist. Noise levels are measured at different distances to capture the sound pressure levels (SPLs) reaching the human ear at different pressure and intensity levels because of the fact that sound level depends on the distance between the sound source and the place of measurement. The SPL decreases with doubling of distance by (−)6 dB. It falls on the 1/2 fold (50%) of the initial value of the sound pressure. The sound pressure decreases with the ratio $1/r$ to the distance. Even the sound intensity decreases by one-fourth (25%) of the initial value of sound intensity.

The characteristics of the equipment measured in each dental learning area are noted in Table 1.

The sound level meters employed were $L_{A(eq)}$ (equivalent to continuous sound level in a specific time interval) and $L_{pk(max\ p)}$ (highest value).

The data were collected, tabulated, and statistically analyzed using *t*-tests with significance level set at 5%.

RESULTS

The results of the noise levels of equipments measured in dental laboratories at two distances of 6 inches and 2 m as

Table 1: Characteristics of the equipments measured

Dental learning areas	Equipment	Year of manufacture	Brand/model
Laboratories	Cutting equipment	2000	Confident, CDEL 08-02 c49 049
	Polishing equipment	2000	Kavo EWL
	Vibrating equipment	2001	Kavo EWL 5403
	Lathe trimmer	1994, 1998	Unident 501
	Casting machine	2004	Unident
	Micromotor	2003	Marathon SDE SH 375 1101037
Pre-clinical	Contra angle handpiece (brand new)	2003	NSK
	Contra angle handpiece (used)	1999	NSK
	Straight handpiece (brand new)	2003	NSK
	Straight handpiece (used)	1999	NSK
Clinic	Turbine (brand new)	2003	NSK
	Turbine (used)	1999	NSK
	Contra angle handpiece (brand new)	2006	NSK
	Contra angle handpiece (used)	1999	NSK
	Straight handpiece (brand new)	2006	NSK
	Straight handpiece (used)	2001	NSK
	Ultrasonic scaler	2003	NSK
	Suction pump		

explained before are shown in Table 2. The results of the noise levels of used and brand new equipments measured in pre-clinical and clinical areas are shown in Tables 2–6.

The noise levels measured varied between 64 and 97 dB(A), being very high in Gypsum Laboratory where values of $L_{A(eq)}$ were from 80.8 to 95.06 dB(A). Significant differences in noise levels between 6 inches and 2 m from the operator in laboratories were found at $P<0.05$. The average value of difference (cutting against only turned on) was equal to 9 dB(A) [Figure 2]. Mean noise levels with highest maximum value recorded during various cutting activities were highest on metal with 16.17 dB(A) of average difference [Figure 3]. In general, the used equipment was noisier between 1 and 9.44 dB(A) more than the brand new ones and had an average of about 3.91 dB(A) difference (t=8.54 and $P<0.001$) [Figure 4]. The laboratory engines had the highest noise levels, whereas the noise levels in high-speed turbine handpieces and the low-speed contra angle handpieces were decreased.

DISCUSSION

Exposure to noise constitutes a health risk. There is

Table 2: Noise levels [dB(A)] of dental laboratory engines

Laboratory engines	6 inches (mean±SD*)	2 m (mean±SD)	*t* value	*P* value
Cutting equipment	81.9±0.91	74.2±1.91	3.39	<0.001
Polishing equipment	78.6±7.03	72.4±4.47	2.35	<0.05
Lathe trimmer	87.8±6.77	76.03±3.84	4.78	<0.001
Vibrating equipment	93.1± 2.64	81.2±0.64	3.72	<0.002
Casting machine	74.1±1.36	70.4±1.41	5.97	<0.001

Table 3: Noise levels [dB(A)] of contra angle handpiece in pre-clinical area

Contra angle handpiece	Used (mean±SD)	Brand new (mean±SD)	*t* value	*P* value
Only turned on	64.1±1.07	63.1±1.99	1.35	0.179
Cutting on typhodont	69.3±1.71	62.4±1.3	3.87	<0.001
Cutting on extracted tooth	71.3±2.1	69.5±1.08	2.40	<0.05
Cutting on acrylic	73.8±2.8	71.2±1.44	2.55	<0.02

Table 4: Noise levels [dB(A)] of straight handpiece in pre-clinical area

Straight handpiece	Used (mean±SD)	Brand new (mean±SD)	*t* value	*P* value
Only turned on	64.6±1.99	62.9±2.18	1.82	0.085
Cutting on typhodont	66±0.37	62.8±1.37	2.68	< 0.02
Cutting on extracted tooth	73.3±1.96	72±1.76	1.56	0.136
Cutting on acrylic	78.8±3.47	76.7±1.89	1.68	0.110

Table 5: Noise levels [dB(A)] of equipments in clinical area

Equipment	Used (mean±SD)	Brand new (mean±SD)	*t* value	*P* value
Ultrasonic scaler without suction pump	79.4±3.27	74.4±1.53	3.92	<0.001
Ultrasonic scaler with suction pump	83.8±1.78	76.1±5.33	3.92	<0.001
Turbine				
Only turned on	68.9±2.17	66.7±2.2	2.19	<0.05
Cutting on tooth	77.64±1.88	73.8±2.3	4.03	<0.001
Cutting on acrylic	79.78±1.76	75±2.19	5.33	<0.001
Cutting on composite	77.5±2.96	76.59±3.43	0.67	0.533
Cutting on amalgam	78.8±1.46	73.8±3.28	3.92	<0.001
Contra angle handpiece				
Only turned on	65.1±2.62	63.2±1.84	1.875	0.077
Cutting on tooth	74.7±1.8	71±1.3	5.20	<0.001
Cutting on acrylic	78.6±0.75	72.2±1.5	11.97	<0.001
Cutting on composite	79.8±1.21	73±3.38	2.45	<0.05
Cutting on amalgam	75.9±0.96	71.3±1.43	8.54	<0.001
Straight handpiece				
Only turned on	67.3±2.95	62.4±1.41	2.17	<0.05
Cutting on tooth	73.4 ±1.9	71.7±1.15	2.55	<0.02
Cutting on acrylic	76.7±3.54	73.8±1.45	2.389	0.028
Cutting on composite	68.6±0.61	64.9±2.09	2.3	<0.05
Cutting on amalgam	72.9±4.94	71±2.88	1.05	0.307

Table 6: Noise levels [dB(A)] of suction pump in clinical area

Equipment	Low volume (mean±SD)	High volume (mean±SD)	*t* value	*P* value
Suction pump running free	71.9±1.18	79.3±1.8	10.81	<0.001
Suction pump touch mucosa	80±1.77	87.2±1.52	9.64	<0.001

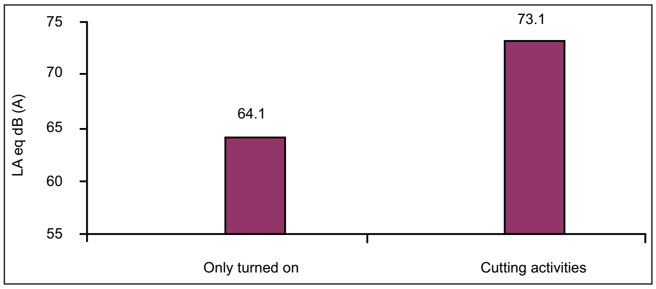

Figure 2: Average noise levels compared between cutting and non-cutting (only turned on) activities. Note the average value of difference being +9 dB(A)

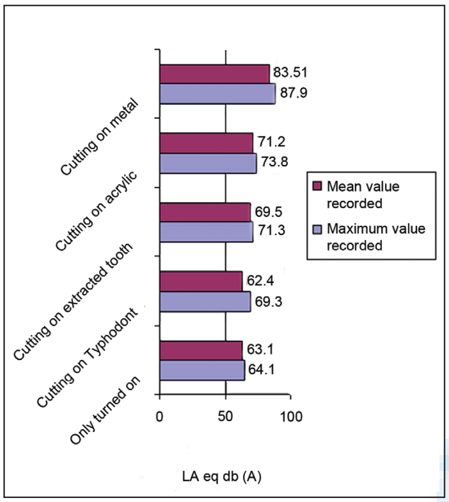

Figure 3: Mean noise levels with highest maximum value recorded during various cutting activities. Noise levels presented are in $L_{A(eq)}$ dB(A)

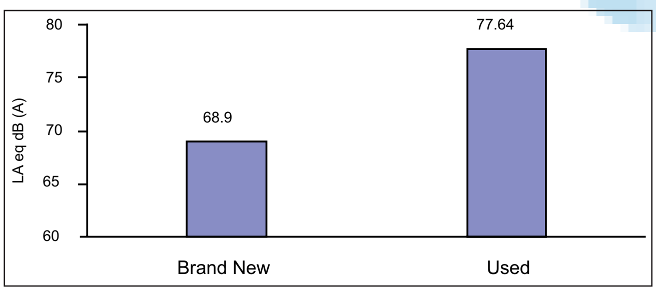

Figure 4: Average noise levels of used and brand new dental turbine compared

sufficient scientific evidence that noise exposure can induce hearing impairment (NIHL), hypertension and ischemic heart disease, annoyance, sleep disturbance and decreased learning performance.[1-17] Degree of risk to individual dentists depends on several factors such as intensity and type of noise, period of exposure each day, total work duration, distance from the source, and individual age and susceptibility.[1,12,18,19,20]

In this study, the noise levels of equipments were measured in dental learning areas under different working conditions. The noise levels measured in this study were similar to that measured in other international studies of noise in dentistry. But the noise levels of the different equipments in this study seem to be higher by +1–+8.4 dB(A) than those found in other countries[1,9,18]. Noise levels for suction pump were 80 dB(A) in this study, whereas in the United Kingdom[1] they were 68–70 dB(A) and in Portugal they were 72 dB(A).[9] Noise levels for the turbine were 75–81 dB(A) in this study, whereas in the United Kingdom, Portugal and Saudi Arabia they were 70–75 dB(A), 68–76 dB(A) and 72 dB(A), respectively; for contra angle handpiece they were 70–76 dB(A) in this study, whereas in United Kingdom, Portugal and Saudi Arabia they were 72–75 dB(A), 69–75 dB(A) and 68 dB(A), respectively.[1,9,18]

Noise levels of equipments in cutting activities compared to non-cutting (only turned on) showed that the noise levels measured during cutting activities were significantly higher to those found when only turned on. The average value of the difference was equal to +9 dB(A), where values ranged from +1 to +13 dB(A) [Figure 2].

However, Fernandes *et al*. presented average values of +6 dB(A), and Bahannan presented average values of +10 dB(A), in similar conditions of measurement in Portugal and Saudi Arabia, respectively.[9,18] Specifically, the noisiest cutting operation was on metal with 16.17 dB(A) of average difference, followed by cutting on acrylic resin [10.86 dB(A)], amalgam [8.77 dB(A)], composite [8.19 dB(A)], cutting on extracted tooth [7.95 dB(A)], cutting on teeth [6.82 dB(A)], and typhodont [3.32 dB(A)] [Figure 3]. This difference in noise levels may be attributed to variations in the composition of materials being cut.

Noise levels of used equipments compared to brand new equipments in the clinics showed that the noise levels produced by used turbine were significantly higher than those produced by the brand new turbine [Figure 4]. The increase in noise levels of used turbines could be an indication of bearing failure.[21] The bearing resistance is affected by wear, not only of the metal surfaces, but also of the ball-cages, when roughness contributes to friction.

In pre-clinical area, there was no significant difference between used and brand new contra angle handpieces when only turned on. But significant differences were found when cutting on typhodont (P<0.001), extracted tooth (P<0.05) and acrylic (P<0.02). There were no significant differences between used and brand new straight handpieces when only turned on. There was significant difference only when cutting on typhodont (t=2.68, P<0.02).

In this study, the high-speed turbine was the noisiest equipment compared to low-speed contra angle and straight handpieces [Figure 5]. This agrees with the findings of Bahannan *et al*.[18] Altinoz *et al*.[22] and Fernandes *et al*.[9] Altinoz *et al*. indicated that under any working condition (under free working conditions without burs, with fissure burs, with flare burs, with round burs, with inverted cone burs), high-speed dental air turbines emit noise at frequencies that may cause hearing loss over time. Higher noise levels emitted by dental turbines may be attributed to variations in the aerodynamic and structural components of each handpiece. The aerodynamic component is a result of the turbulence in the air flow path, whereas the structural component is primarily a result of the bearings of the air turbine rotor.[18]

The suction pump used in the clinical area was affected by the position of the tip. When the tip touched the mucosa, the intensity of noise increased as the soft tissue was caught in the air stream. The high-volume aspirator produced significantly higher noise level than low-volume aspirator (t=9.64, P<0.001). Significant differences were found between used and brand new ultrasonic scalers when used with or without suction pump (P<0.001). Ultrasonic frequencies (sounds above the range of human hearing) can also damage hearing due to the generation of subharmonics. The nonlinear interaction of ultrasound with matter (such as when the energy is scattered at an air–water interface, or in the ear itself) creates subharmonics that fall within the range of human hearing. These subharmonics are perceived as squeaking sounds. This finding highlights the necessity of hearing protection against these frequencies.

Dental laboratories in dental teaching institutions are the areas of highest noise levels when compared to other dental learning areas. The noisiest laboratory equipment recorded in this study was Gypsum vibrating equipment with an $L_{A(eq)}$ of 93.1±2.64 at 6 inches distance. The $L_{pk(max\ p)}$ (highest value) recorded was 97 dB(A). This agrees with the findings of Fernandes *et al.* who indicated that gypsum laboratory is the area of highest noise levels due to the frequent use of gypsum vibrator.[9]

At the hospital laboratories, all the laboratory work is carried out in a single, medium-sized room. Since the working environment is restricted to one room, each technician carries out every stage of their lab work simultaneously for their cases. Hence, the technicians and dental students are exposed to noise levels as high as 99 dB (A) at times during the day. This might affect the students, technicians and teachers in their work efficiency.

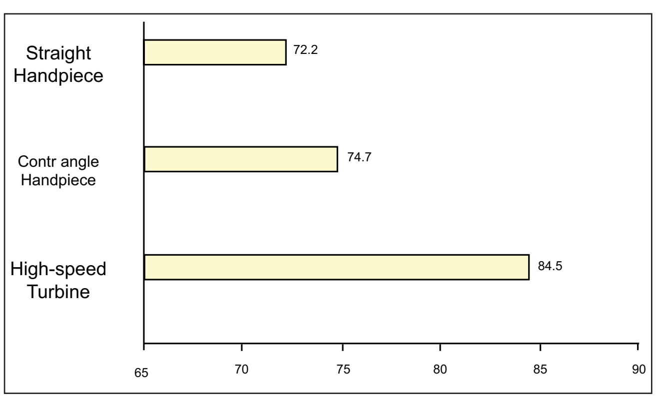

Figure 5: Mean noise levels of different dental handpieces. Noise levels presented are in $L_{A(eq)}$ dB(A)

The effect of noise on learner comfort affecting the work performance and mental efficiency has been researched.[4,5,14-16] Noise can induce learned helplessness, increase arousal, alter the choice of task strategy, and decrease attention to the task. Performance of a task involving a motor and monotonous activity is sometimes not only decreased, but also on the contrary, is enhanced.[4] The importance of noise reduction in dental learning areas is obvious, especially for teachers and students, as high level of noise exposure is relatively continuous in such settings.

Comparison of noise levels measured in this study with legal limits sheds light on acoustic environment of dental learning areas. According to the Central Pollution Control Board (CPCB) standards in India, 50 dB(A) is the limit of $L_{A(eq)}$ in ambient air for sound levels in silent areas which include hospitals, teaching institutions and libraries. The values obtained in all the evaluated areas in this study were exceeding the permissible limit as compared with CPCB values [Figure 6]. Fernandes *et al.* suggest the classification given by Cavanaugh to set a limit value in places of learning in dental teaching institutions. Accordingly, 56 dB(A) could be adequate as the upper limit value for a relaxed communication at a normal tone at 3 m.[9]

Comparison of noise levels in this study with some European limits indicated that they did not comply with these laws[9] [Table 7].

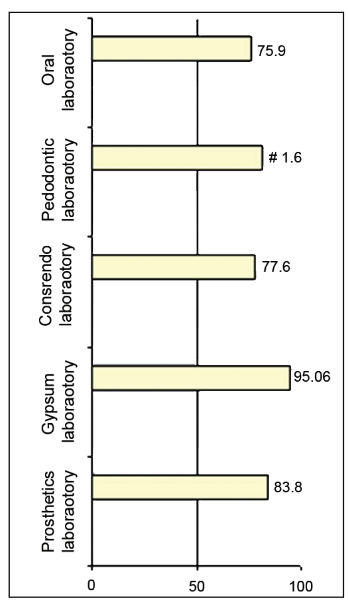

Figure 6: Average noise levels in different dental learning areas compared with CPCB value of 50 dB(A). Note that all dental learning areas exceed the limit value

Table 7: International legal limits for equipment noise levels

Countries	Legal limits for equipment sound levels in $L_{A(eq)}$ [dB(A)]
India (CPCB)	≤50
Portugal	≤46
Italy	≤40
France	≤38
Sweden	≤35

According to ISO Recommendation R 1999, noise-induced hearing impairment does not occur at 75 dB(A) and lower. This value is equal to the value specified in 1980 by the World Health Organization.[4] For impulsive noises with $L_{A(eq)}$>80 dB(A), studies on temporary threshold shifts suggest the possibility of an increased risk for impulse noise induced hearing impairment in adults.[4] In clinical areas, operators use their turbine handpieces in short bursts, ranging from 5 to 45 seconds, which is a typical example of an impulse noise commonly seen in dentistry.

The Williams-Steigner Occupational Safety and Health Act, or OSHA, of 1970 was an attempt to provide working environments, which are free of pollutants and other hazards. Occupational noise exposure was one of the areas covered by Part 1910 of Title 29 of the code of Federal Regulations in 1974. The noise exposure limits set by the OSHA (1972, 1981) are among the best known criteria. The basic daily exposure limit is given by

$$T = 8/2^{(L-\mathrm{CL})/\mathrm{ER}}$$

where T is the allowable exposure time (hours/day), L the noise level in dB(A), CL the criterion level [=90 dB(A)], and ER is the exchange rate [=4 dB(A)].

Noise exposure for a worker during a day can be calculated by using the following formula:

$$L_{A(EP,d)} = 10 \log_{10}[1/8 \sum T_{k.} 10^{(0.1L}{}_{A(eq)tk}{}^{)}]$$

OSHA standards would permit exposure of about 7 hours/day at 91 dB(A). National Institute of Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC) assessed hearing impairment as a function of the levels and durations (e.g., 40-year working lifetime) of occupational noise exposure. Thus, for a 40-year lifetime exposure in the workplace to average daily noise levels of 80, 85, or 90 dBA, the excess risk of material hearing impairment was estimated to be 3, 16, or 29%, respectively. OSHA used these estimates as the basis for requiring Hearing Conservation Programs (HCP) for occupational noise exposures at or above 85 dB(A) for 8 hours of Time Weighted Average (TWA) [46 Fed. Reg. 4078 (1981a)].

Daily cumulative drill noise of 12–45 minutes falls within the recommended OSHA guidelines.[24] However, the older drills produce 100 dB or more, and the allowable exposure durations are reduced to about 2 hours/day, according to the OSHA guidelines, which does not ensure against significant hearing loss after long-term noise exposure.[24] The regulation states that every employer should provide each of his employees, who is likely to be exposed to 85 dB(A) or above, with adequate information, instruction, and training on the risk of damage to that employee's hearing that such exposure may cause.

NIHL is usually undetected until damage to the inner ear is advanced. There is no treatment for NIHL.[25] The other side of the coin is that NIHL is an almost wholly preventable disease and adequate preventive measures are available. It is imperative that an Hearing Conservation Program (HCP) be instituted in noisy work places.[25] Where regulations do not exist for the need to have an HCP, a proactive role must be taken. The elements of an effective HCP include a noise survey, engineering controls, administrative controls and personal hearing protectors.

Noise survey

An HCP should always begin with a preliminary noise survey.[25] The objective of the preliminary noise survey is to identify areas in the workplaces where workers are exposed to hazardous noise levels. The detailed noise survey obtains information of noise levels at various workplaces so as to develop guidelines for engineering and administrative controls. It will also define areas where hearing protection is necessary and identify those employees who would be included in the audiometric testing program.

Engineering controls

Noise control through engineering control[25] is the most important control measure in an HCP. It is the only method that controls the noise levels while others control exposure to noise. Noise can be controlled either at the source or in the path.

Measures of controlling noise at the source include replacing or substituting equipment with less noisy equipment, moving the source further away from the operator, reducing vibration by vibration absorbing material and the use of silencers for air and gas flow.

Measures of noise control in the path should provide acoustic shields, barrier walls and partial or total enclosures of noise sources. In essence, noise control could involve equipment replacement, equipment relocation, vibration isolation, surface damping and barriers, enclosures or mufflers, and last but not the least, a source re-design.

Administrative controls

When engineering controls are not feasible, administrative controls[25] can be implemented by switching the employees in high noise areas with those in low noise areas after a certain period of time has elapsed. It could also involve scheduling operating times so as to minimize the number of employees exposed to high noise levels.

Exclusion from noise exposure of those who are most susceptible to NIHL is severely limited because individual susceptibility is almost certainly multifactorial, with anatomic, biochemical, pathologic, and multiple other aspects.

Hearing protectors

In the 1960s, Dr. Howard E. Kessler, a Cleveland dentist, seemed to have been the main spokesperson for ear protection in the dental office.[26] In 1968, von Krammer warned against chronic acoustic trauma from the turbine, which was irreversible, and recommended custom-made earplugs or earmuffs.[27] Dr. Jerome S. Mittleman recommended that cotton saturated in olive oil and squeezed of excess be used as earplugs to minimize the hazard.[26] The American Council on Dental Materials and Devices[2] in 1974 also recommended personal protection through the use of earplugs (cotton with petroleum jelly, defibered soft glass, or plastic plugs, capable of 20–35 dB reduction). Hearing protection with the use of earmuffs or plugs is instituted to supplement the other control measures. The primary objective in using hearing protectors is to economically reduce hazardous exposures to safety levels at the ears of employees to prevent hearing loss. Earplugs are inserted into the ear canal, whereas earmuffs cover the entire external ear by means of a sealed cup. They both decrease the intensity of noise by 30–35 dB without interfering with the conduct of a normal conversation between persons in the laboratory. The choice between the two depends on the level of noise and its frequency spectrum and on certain other factors of the working environment. Generally, plugs provide less noise attenuation than muffs and are useful in noise levels up to 100–105 dB(A). Muffs are normally considered satisfactory up to 110–115 dB(A).[1]

Personal evaluation

As early as 1959, Dr. Jerome S. Mittleman recommended that regular audiograms be taken of dental personnel to check for hearing loss resulting from use of the air turbine handpieces and ultrasonic scaler.[26] In 1960, Dr. Howard Kessler also recommended regular audiometric checkups for the dentist performed by an audiologist. Kessler, who was also a dentofacial speech consultant, explained how an audiogram could be used to graph the degree of hearing loss for several high and low frequencies.[26] Shifts of hearing thresholds have been found at 6 and 4 kHz in the dentists working in dental clinic areas of a dental school.[28] This presents a situation that places emphasis on the importance of regular personal evaluation. The Council on Dental Materials and Devices also recommends that practitioners concerned about the potential impairment should have an otologic examination and audiometric evaluation in a silent room, to assess the present situation. An audiometric evaluation should be made after a typical workday and again at the beginning of the next day to observe temporary threshold shift and apparent recovery.[2]

The noise levels detected in this study were considered to be close to the limit of risk of hearing loss. However, dental technicians and other personnel working all day in noisy laboratories could be at risk of NIHL. Regular exposure to high noise levels in dental learning areas adversely affect the ability to learn. Dental learning areas inevitably suffer from noise pollution due to the use of diverse equipments which emit noise. It is impossible to protect individuals from every type and degree of hearing injury. The direction should be to prevent occurrence of severe impairment and to retard the development of established injury. The risks of harmful effects must, therefore, be considered and the preventive and evaluation measures may be undertaken in dental teaching institutions for acoustic comfort.

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How to cite this article: Kadanakuppe S, Bhat PK, Jyothi C, Ramegowda C. Assessment of noise levels of the equipments used in the dental teaching institution, Bangalore. Indian J Dent Res 2011;22:424-31.

Source of Support: Nil, **Conflict of Interest:** None declared.