

Should Dentists Mandatorily Wear Ear Protection Device to Prevent Occupational Noise-induced Hearing Loss? A Randomized Case–Control Study

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Received : 02-02-22

Revised : 15-04-22

Accepted : 14-07-22

Published : 31-10-22

ABSTRACT **Objectives:** Dentists are constantly exposed to high-frequency noise at their workplace that increases the risk of occupational noise-induced hearing loss (ONHL). Even though dentists acknowledge about the noisy dental workplace, hearing protection devices or ear protection devices (EPD) are not commonly used by dentists. No study has yet provided any evidence on how effective EPDs can be in reducing the temporary threshold shift and damage to the outer, middle and inner ears. The aim of this article is to evaluate and compare the changes in the hearing acuity and temporary threshold shift (TTS) in dentists who wear EPDs when compared with those who do not use EPDs. **Materials and Methods:** Sixty-four dental clinicians were randomly divided into two groups: Group 1 (performed ultrasonic scaling without EPDs) and Group 2 (performed ultrasonic scaling with EPDs). Their hearing threshold was checked by using pure tone audiometry, stapedial acoustic reflexes, and otoacoustic emission (OAE) before and after 45 mins of ultrasonic scaling. The intergroup and intragroup comparison was done. All the outcome measures from pre- and post-scaling across the ears, groups, and frequencies among groups were done using mixed-effects analysis of variance. A *P*-value of less than 0.05 was considered to be statistically significant. **Results:** EPDs were effective in reducing the immediate TTSs. Immediately upon exposure to high-frequency noise, the alterations in the hearing threshold and stapedial reflex OAE were less in the group that used EPDs. **Conclusion:** EPDs should be mandatorily worn by dentists to prevent accumulation of temporary shifts in the hearing acuity, which in long-term can lead to permanent hearing loss.

KEYWORDS: Dentists, ear plugs, ear protection device, noise, occupational hazard, occupational noise induced hearing loss, scaling, ultrasonic scalers

INTRODUCTION

Noise is defined as an unwanted and undesirable sound in the environment.^[1] Noise is one of the leading causes of work-related diseases or injuries, especially affecting the auditory system.^[1] The hearing loss that arises from prolonged noise exposure at the workplace is known as occupational noise-induced hearing loss or boiler-makers notch (ONHL or NIHL). According to the Occupational Safety and Health Administration (OSHA), around 30 million people

suffer from ONHL due to harmful levels of noise at their workplace.^[2] Among all the occupations, dentists and dental auxiliaries are at an increased risk of developing ONHL due to prolonged and continuous exposure to high-frequency noise in their workplace.^[3-6]

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How to cite this article: Mohan KM, Chopra A, Guddattu V, Singh S, Upasana K. Should dentists mandatorily wear ear protection device to prevent occupational noise-induced hearing loss? A randomized case-control study. J Int Soc Prevent Communit Dent 2022;12:513-23.

Access this article online

Quick Response Code:



Website: www.jispcd.org

DOI: 10.4103/jispcd.JISPCD_28_22

The prevalence of hearing loss among dentists is 5–20%.^[7-13] Other dental professionals that use various noise-inducing dental equipments include dental nurses, dental technicians, clinical dental technicians, orthodontic therapists, and dental hygienists. Dentists are exposed to 70–120 dB of high-frequency noise for more than 8 h in a day, which is around 8% of their 24 h noise exposure.^[6-13]

The most common dental instruments and equipment that emit high-frequency noise include high-speed turbine handpiece (airotor or micromotors); high-velocity suction; stone mixers and grinders; sonic and ultrasonic scalers, ultrasonic cleaners, and vibrators; model trimmers; and other mixing devices.^[6-14] Among all these instruments, ultrasonic scalers are one of the most common instruments known to emit high-frequency noise in a dental setup. Ultrasonic scalers produce noise levels between 87.1 dBA to 107 dB, at the one-third octave band of 25,000 Hz.^[7-9,15-17] Although the measurement of 107 dB is above the recommended 87 dB, human ears are insensitive to this ultra-high frequency.^[17,18]

Previous studies have shown that ultrasonic scalers can cause a temporary threshold shift (TTS), whereby an individual requires a louder stimulus than usual to hear the same frequency.^[19] This temporary condition was found to last between 16 h to 48 h, but the researchers have also cautioned that a certain degree of permanent damage can occur.^[19] A continuous exposure to more than 100 dB for more than 8 h increases the risk of permanent hearing loss from 94.5% to 99.5%.^[6-10,15-38] Previous studies have shown that approximately 7–20% of the dental hygienists, dental assistants, and dentists report problems such as difficulty in communication, annoyance, conversation interference, concentration difficulty, hearing loss even at speech frequencies.^[14-17,32-37]

Although the presence of ONIHL among dentists is well established, preventive measures and use of hearing protection device (HPD) or ear protection device (EPD) among dentists are not widely advocated and used. Many dentists are unaware about the immediate and long-term side effects of work place noise and its effects on the auditory and non-auditory systems. Dentists are even reluctant to use are unaware about the importance of EPDs in a dental setup. Hence, it is crucial to generate evidence on the efficacy of using EPDs in a dental set up. No study has yet compared the immediate changes in hearing acuity of dentists who use EPDs when compared with those who work without EPDs. Hence, the present study aims to

evaluate and compare the efficacy of using an EPD in preventing the TTS among dentists while performing ultrasonic scaler. The study is of global significance as it lays the foundation and highlights the importance of using EPDs by dental professionals to protect their ears while working in a noisy workplace.

MATERIALS AND METHODS

STUDY DESIGN AND SETTINGS

The study was conducted at the Department of Periodontology, Manipal College of Dental Sciences, Manipal, Karnataka, India, in collaboration with the Department of Speech and Hearing, Manipal College of Health Professions, Manipal Academy of Higher Education, India, between September 2017 and December 2018 in accordance with the Helsinki Declaration of 1975, as revised in 2000. Before the data collection, the ethical permission was obtained from the Institutional Review Committee IEC no.: 323/2017 and registered at the Clinical Trial registry with No. CTRI/2017/07/009031 registered on 12/07/2017. The following instruments, test, and methodology were adopted for the study.

SAMPLE SIZE AND PARTICIPANTS

The sample size was calculated on the basis of the formula with 95% confidence interval, 80% power, ratio of cases to controls=1, and standard deviation between cases and controls: 0.5, $Z\text{-beta}=0.84$, $Z\text{-alpha}/2=1.96$. A total of 64 participants were required for the study. A total of 70 dental practitioners aged 20–35 years of age (both males and females) were initially screened in the study after taking written and oral informed consent.

All participants were screened for the presence of any previous or existing ear and hearing problem with the following inclusion criteria: (a) hearing sensitivity below 15 dBHL (hearing loss in decibel) in both the ears; (b) no previous history of any ear infection; (c) no history of any trauma to the head and neck region; (d) no systemic illness or history of any drug intake; and (e) no history of any nerve injury or trauma involving the central or peripheral nervous system. Exclusion criteria were as follows: hearing threshold above 15 dBHL in both the ears; those with a history of previous ear infection; head and neck injury; nerve injury, sinusitis, tonsillitis; and pregnant or lactating mothers.

OUTCOME MEASURES

The hearing sensitivity was checked for all the participants by performing audiometric testing. All tests were repeated three times for both the ears for all the participants:

- a. *Pure tone audiometry (PTA)*: PTA is the standard behavioral assessment of an individual's hearing sensitivity.^[28,33,34] A calibrated inter-acoustics AC-40 clinical audiometer with standard accessories (TDH-50 Headphone and Read Ear B-71 Bone Vibrator) was used to estimate hearing thresholds. PTA provides information about the peripheral hearing acuity across human audible frequencies and allows clinicians to compare the hearing sensitivity between both the ears.^[39-51] PTA was performed by a duly calibrated (ANSI S3.43–1996) Inter-acoustics AC-40 Double-Channel Clinical Audiometer coupled with standard accessories [Telephonics Dynamic Headphone (TDH-50P) and Radio Ear B71 Bone Vibrator]. The threshold estimation was done using a modified Hughson–Westlake procedure for the air conduction (250 Hz to 8 kHz) and bone conduction (250 Hz to 4 kHz) 36. The subjects were instructed to indicate by raising their finger if any sound was heard. The changes in the overall hearing sensitivity was evaluated based on the change in the response for each frequency (250, 500, 1000, 2000, 4000, 8000 Hz).
- b. *Tympanometric test* was performed for both the ears using a calibrated (ANSI 3-39-1987) Immittance audiometer (GSI-Tympstar). The tympanometric test indirectly reflected the middle ear status by assessing changes in the ear canal volume, middle ear pressure, and static compliance.^[33] Further, the stapedial acoustic reflex was elicited for the frequencies 500, 1000, 2000, and 4000 Hz with presentation levels starting at 85 dBHL. The presence of reflex is considered when the deflection is 0.03 mL in compliance.
- c. *Otoacoustic emission (OAE) test*: A transient evoked OAE from the inner ear was measured for five frequencies (1000, 1414, 2000, 2828, and 4000 Hz) using a calibrated ILO-OAE system (Version 6.38.25.0). The amplitude of OAE was recorded for all the five frequencies for both the right and left ears. Any signal-to-noise (SNR) ratio above 6 dB in amplitude was considered as a sign of the presence of OAE. Any change in the number of OAE received before and after exposure to noise was recorded to evaluate the state of the inner ear.^[33]

After the evaluation of initial hearing acuity, six participants were excluded because of the loss of hearing acuity (hearing sensitivity below 15d BHL in both the ears) and the presence of ear infection. Thus, a total of 64 participants were recruited for the study. Age (in years), gender (M/F), duration of scaling (min), hours spent in the dental clinics (in min), total

work experience (in years), and baseline noise in the workplace (Hz) were recorded.

Noise measurement of the dental workplace was done to measure the maximum and minimum noise levels available. The minimum noise measurement corresponded to the sound level meter reading when dental instruments are being used. Similarly, the maximum noise corresponds to the sound level meter reading when all the dental types of instruments and equipment are working. A minimum of three readings were taken, one at the center of the workplace and four at the corners of the room, to evaluate the overall distribution of noise in the workplace. Successively, noise measurements were taken for a single ultrasonic scaler. The average of all the three readings and the difference between the maximum and minimum readings were noted.

GROUPING, BLINDING, AND INTERVENTION

After the baseline audiometric testing and noise measurements, the participants were randomly divided into two groups (group 1 and group 2) using the coin toss method. All participants in group 1 were asked to use the ultrasonic scaler (Parkell Auto/Manual Tuned Ultrasonic Scaler) at 25,000 Hz and medium power settings; power 110 V, 50/60 Hz, 100 VA for removing the hard and soft deposits from the surface of teeth for 45–60 min without wearing any EPDs. The participants in group 2 were asked to perform ultrasonic scaling by using an ultrasonic scaler (Parkell Auto/Manual Tuned Ultrasonic Scaler) for only 45–60 min after wearing the same type of EPD (Foam Plugs Classic Soft, Eggar, India) with noise attenuation properties (SNR: 36, *H*-value: 36 dB, *M*-value: 33 dB, *L*-value: 29 dB) [Figures 1 and 2].

The participants were demonstrated and trained to wear the EDPs as follows: the participants were requested to first roll the earplug into a small and thin shape with their fingers (single or both hand) and pull the top of the ear in an upward and backward direction with their opposite hand to straighten out their ear canal. The rolled-up earplug should then be carefully put inside the ears. The participants should hold the earplug with the finger until it expands to fill the ear canal. The voice should sound muffled when the plug has made a good seal. Once the ear plugs are fitted in both the right and ear ears, the participants were also requested to follow the ergonomically correct operator position and to perform ultrasonic scaling. All participants were requested to maintain a distance of 35–40 cm from the ultrasonic scaler tip and performed ultrasonic scaling for 45–60 min.

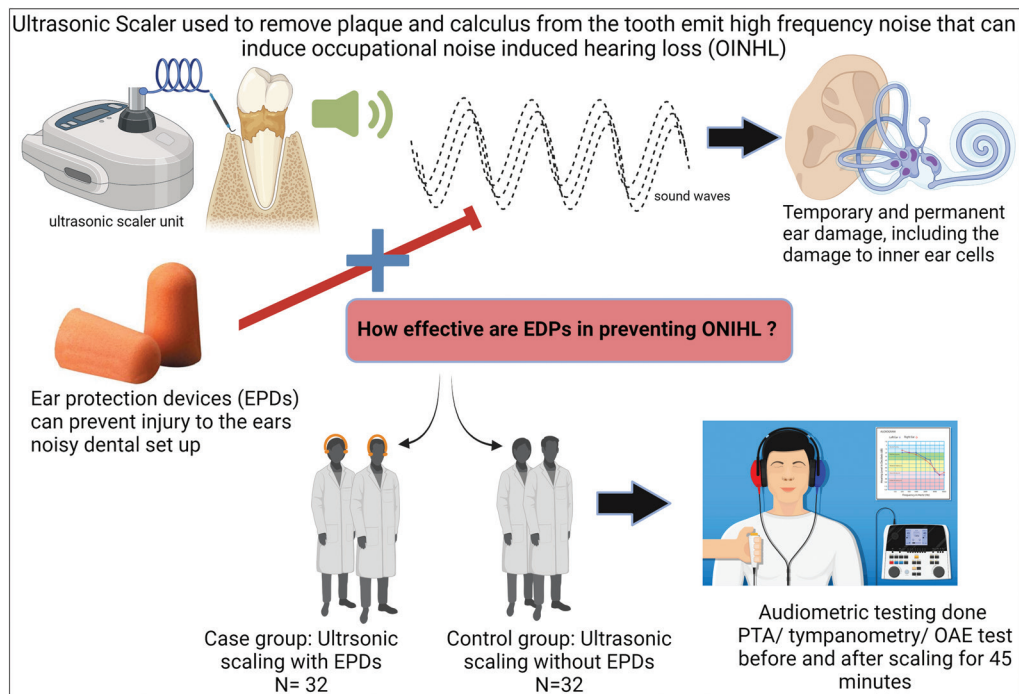


Figure 1: Schematic representation of research question and methodology. PTA= pure tone audiometry; OAE = otoacoustics emission

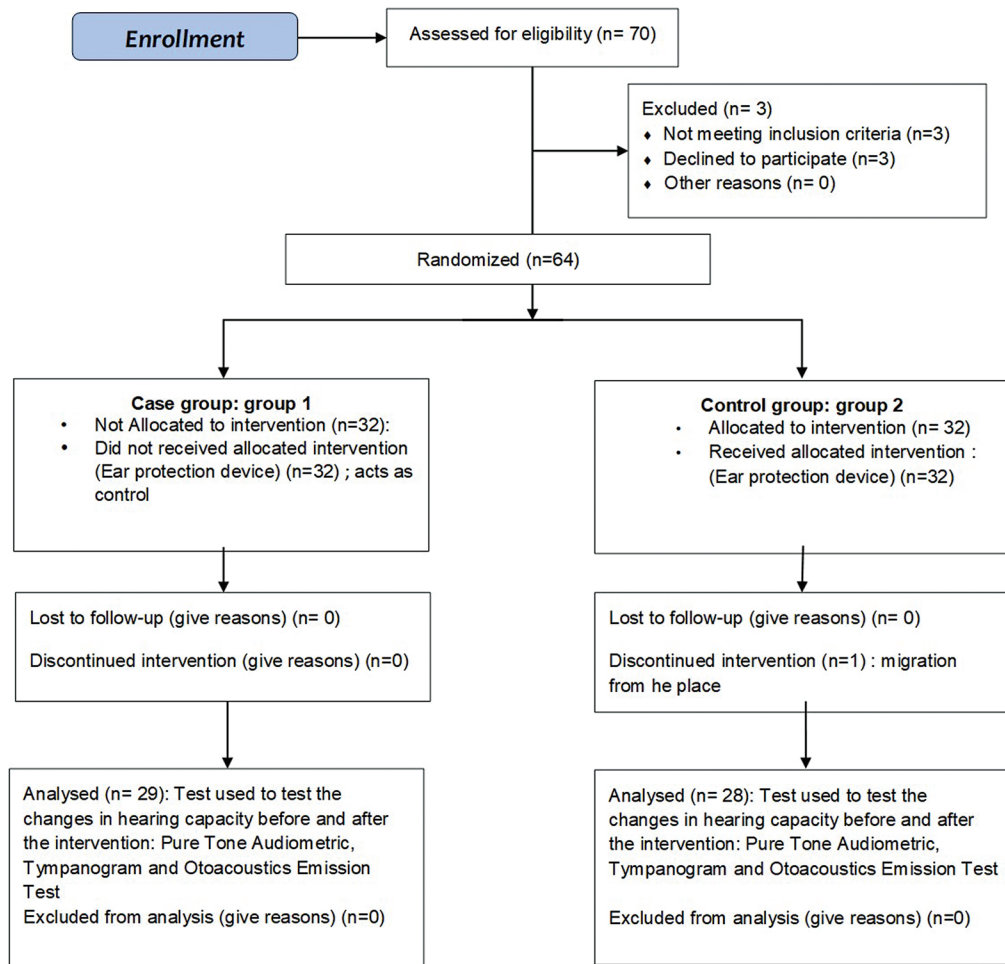


Figure 2: CONSORT flow diagram

Once the scaling was completed, all three audiometric tests were repeated for all the participants for both the left and right ears. The clinicians were also questioned regarding any non-auditory symptoms such as irritation, headache, fatigue, pain in hands, fingers, wrist, or back, dizziness or ringing sensations in the ears, and difficulty in wearing the EDPs. All investigators who performed the audiometric evaluations and statisticians who analyzed the data were blinded about the group assignment.

STATISTICAL ANALYSIS

All data were checked for entry errors and manually entered in a spreadsheet and analyzed with a statistical package, IBM SPSS version 15 (IBM Co., Armonk, NY, USA). Continuous variables [age, gender, duration of scaling, hours spent in the dental clinics, total work experience, and baseline noise in the workplace (Hz)] recorded were summarized by the mean and standard deviation. For intergroup and intragroup comparison of outcome measures from pre- and post-scaling across the ears, groups, and frequency in both the groups, mixed-effects analysis of variance (ANOVA) was used. An overall *P*-value for comparison of mean outcome

measures from pre- to post-scaling across the groups adjusted for the effect of both the ears and frequency was reported. A *P*-value of less than 0.05 was considered to be statistically significant.

RESULTS

The mean age of all the participants was 26.4 ± 4.5 years in the case group and 25.4 ± 4.0 in the control group. There were 30 males and 34 females (group 1—males: 14 and females: 18; group 2—males: 15 and females: 17) in the study. The average noise values recorded on the decibel (dB) scale when one scaler was functioning for three consecutive recordings were 84, 88, and 91 dB. When more than one dental chair was operating, the average noise exceeded 137 dB [Table 1].

PURE TONE AUDIOMETRY

The mean TTS across all the octave frequencies was found to be 1.37 dBHL in group 1 and 1.05 dBHL in group 2. The pre- and post-scaling results for the PTA test showed a significant difference between group 1 and group 2, with a *P*-value of less than 0.045 [Figure 3 and Table 2]. The PTA values for 250 and 500 Hz were increased in group 1 (right ear—pre-scaling:

Table 1: Demographic data and characteristics of the participants

Participant characteristics at baseline and after scaling in both the groups

Total participants recruited= 70; total number of drops outs = 6; final participants = 64

Characteristics	Group 1		Group 2	
	Baseline	Post-scaling	Baseline	Post-scaling
No. of participants included	32	32	32	32
Mean age (years)	26.4 ± 4.5		25.4 ± 4.0	
Gender	Males: 14 and females: 18		Males: 15 and females: 17	
Previous history of ear infection/pain/injury	3	0	3	0
Tinnitus	Nil	4	Nil	0
Work experience (years)	3.7		3.9	
Duration of scaling (min)	40.5		42.3	

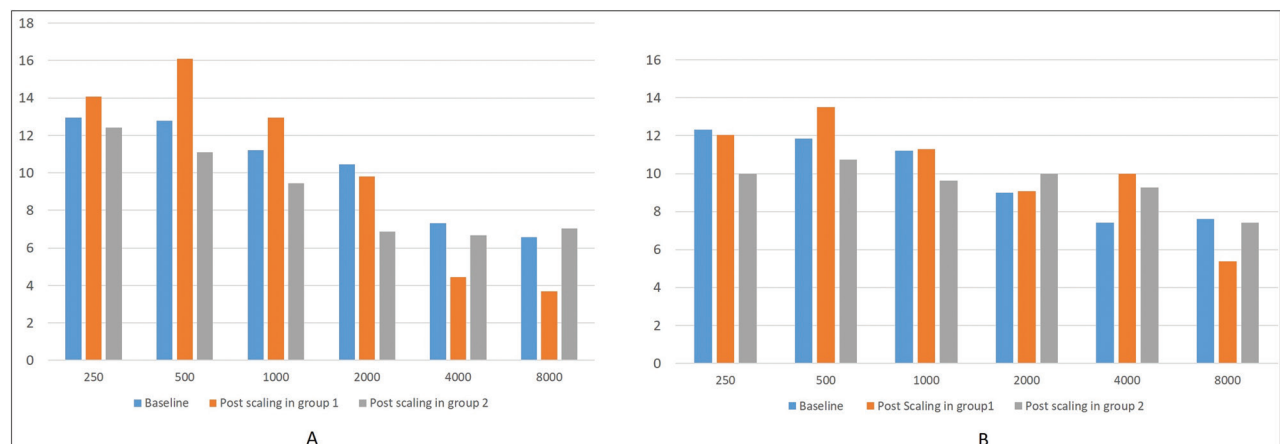


Figure 3: Comparison of the post-scaling pure tone audiometry (PTA) readings of the left ear (A) and right ear (B) in groups 1 and 2 compared with baseline [using mixed-effects ANOVA] at *P* < 0.045; group 1: without ear protection device (EPD); group 2: with EPD

10.56 ± 5.06, post-scaling: 12.04 ± 5.75) when compared with group 2 in which a decrease was noted (right ear—pre-scaling: 14.07 ± 4.60, post-scaling: 10.00 ± 6.79, *P*-value of 0.045 for both the groups). The average reduction in the hearing threshold for group 1 (without EPD) ranged from 0.18 to 2.22 dBHL (right ear) and from 0.16 to 2.22 dBHL (left ear). The difference in pre-post scaling for group 1 was more when compared with group 2 with a mean reduction in right ear ranging from a minimum of 0.94 dBHL to a maximum of 4.07 dBHL. The maximum difference in the hearing threshold was found to be 4.26 dBHL for the left ear. The left ear was more affected than the right ear [Figure 3 and Table 2].

TYMPANOMETRIC TEST (STAPEDIAL ACOUSTIC REFLEXES)

The results of the stapedial acoustic reflexes also followed the trend of an increase in threshold in group 1 and a decrease or comparable threshold shift in group 2 [Figure 4 and Table 3]. The left ear showed more threshold shift with maximum shift seen in the

mid-frequency range. Group 1 showed the trend of elevated reflexes post-exposure with the mean increase in the stapedial reflex threshold found to be 1.87 dB sound pressure level (SPL) (right ear) and 3.9 dB SPL (left ear). When compared with group 1, group 2 showed a decrease in the stapedial reflex threshold with a mean reduction of 3.57 dB SPL (right ear) and 4.64 dB SPL (left ear). In both the groups, the left ear was found to be more affected when compared with the right ear with a *P*-value of less than 0.0383.

OTOACOUSTIC EMISSIONS (OAEs)

The results of the OAE confirmed the effects of high-frequency noise exposure following scaling on the inner ear. There was a decrease in the hearing acuity that ranged from 0.78–1.42 dB (right ear) to 0.75–3.21 dB (left ear) for group 1. When compared with group 1, the difference in the OAE readings was not observed in group 2. The minimum difference in OAE values was found to be 0.29 dB in group 2. The OAE SNR for

Table 2: Pure tone audiometer readings of the left and right ears in both the groups (using mixed-effects ANOVA) at *P* < 0.045 (group 1= group with no ear protection device; group 2= group with ear protection device; A= pre-scaling; B= post-scaling)

Frequency (in Hz)		Group 1 (mean + standard deviation)		Group 2 (mean + standard deviation)		<i>P</i> -value
		Right	Left	Right	Left	
250	A	10.56 ± 5.06	12.59 ± 4.24	14.07 ± 4.60	13.33 ± 7.59	<i>P</i> < 0.045
	B	12.04 ± 5.75	14.07 ± 5.89	10.00 ± 6.79	12.41 ± 6.25	
500	A	11.30 ± 5.64	13.89 ± 3.49	12.41 ± 4.67	11.67 ± 7.72	
	B	13.52 ± 4.34	16.11 ± 3.49	10.74 ± 5.99	11.11 ± 5.43	
1000	A	11.67 ± 4.16	11.30 ± 4.72	10.74 ± 6.46	11.11 ± 7.25	
	B	11.30 ± 4.29	12.96 ± 3.98	9.63 ± 6.19	9.44 ± 6.09	
2000	A	8.89 ± 4.00	9.81 ± 5.27	9.07 ± 6.09	11.11 ± 6.09	
	B	9.07 ± 3.67	9.81 ± 5.09	10.00 ± 6.20	6.85 ± 6.95	
4000	A	4.07 ± 5.37	4.44 ± 4.45	10.74 ± 6.15	10.19 ± 6.27	
	B	2.04 ± 4.22	4.44 ± 4.23	9.26 ± 5.99	6.67 ± 5.88	
8000	A	6.67 ± 5.54	3.52 ± 5.51	8.52 ± 5.85	9.63 ± 6.34	
	B	5.37 ± 6.64	3.70 ± 4.92	7.41 ± 5.78	7.04 ± 5.76	

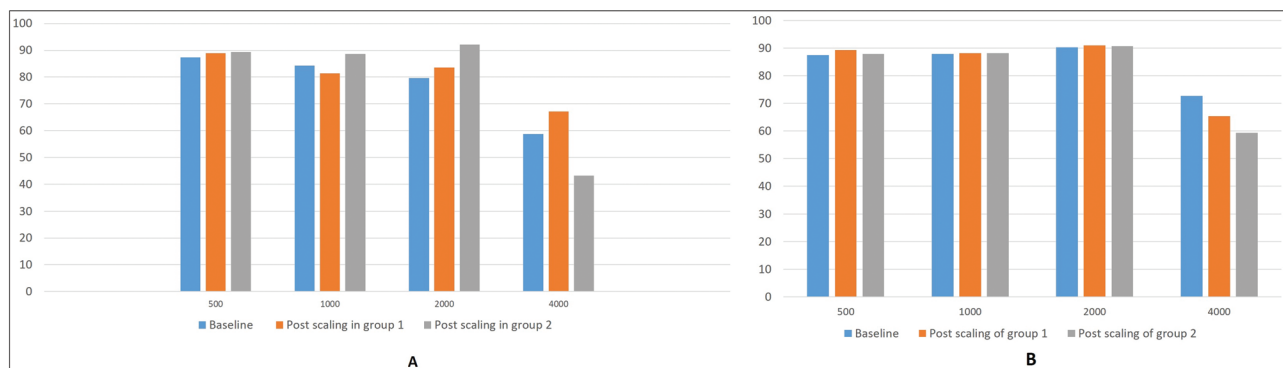


Figure 4: Comparison of the average post-scaling tympanogram readings of the left ear (A) and right ear (B) in both the groups compared with baseline [*P*-value < 0.383 using mixed-effects ANOVA]; group 1: without ear protection device (EPD); group 2: with EPDs

Table 3: Tympanogram reading in the right and left ears in both the groups (P -value < 0.383 , mixed-effects ANOVA; A—before scaling; B—after scaling) (group 1= group with no ear protection device; group 2 = group with ear protection device; A= pre-scaling; B= post-scaling)

Frequency (in Hz)		Group 1 (mean $\pm$ standard deviation)		Group 2 (mean $\pm$ standard deviation)		P -value
		Right	Left	Right	Left	
500	A	89.64 $\pm$ 5.92	88.93 $\pm$ 7.49	85.36 $\pm$ 4.89	85.71 $\pm$ 5.39	$P < 0.0383$
	B	89.29 $\pm$ 5.39	89.29 $\pm$ 5.39	87.86 $\pm$ 5.68	88.93 $\pm$ 8.20	
1000	A	89.29 $\pm$ 5.04	89.29 $\pm$ 6.90	86.43 $\pm$ 4.84	79.29 $\pm$ 22.59	
	B	88.21 $\pm$ 3.65	88.57 $\pm$ 6.50	88.21 $\pm$ 5.30	81.43 $\pm$ 23.99	
2000	A	91.43 $\pm$ 5.58	83.93 $\pm$ 24.28	89.29 $\pm$ 4.65	75.36 $\pm$ 31.47	
	B	91.07 $\pm$ 5.15	92.14 $\pm$ 6.29	90.71 $\pm$ 3.78	83.57 $\pm$ 24.37	
4000	A	87.86 $\pm$ 25.21	52.50 $\pm$ 46.41	57.50 $\pm$ 43.83	65.00 $\pm$ 42.20	
	B	65.36 $\pm$ 42.44	43.21 $\pm$ 44.16	59.29 $\pm$ 45.16	67.14 $\pm$ 43.57	

Table 4: Otoacoustic emissions reading of both right and left ears in both the case and control groups (mixed-effects ANOVA) at 90% confidence interval and $P < 0.042$ (group 1= group with no ear protection device; group 2= group with ear protection device; A= pre-scaling; B= post-scaling)

Frequency (in Hz)		Group 1 (mean $\pm$ standard deviation)		Group 2 (mean $\pm$ standard deviation)		P -value
		Right	Left	Right	Left	
1000	A	7.29 $\pm$ 5.58	8.91 $\pm$ 5.76	10.62 $\pm$ 6.68	8.25 $\pm$ 6.20	$P < 0.042$
	B	5.87 $\pm$ 6.42	5.70 $\pm$ 4.21	8.87 $\pm$ 8.55	7.96 $\pm$ 11.68	
1414	A	14.10 $\pm$ 7.86	15.14 $\pm$ 6.87	18.03 $\pm$ 8.83	18.82 $\pm$ 7.08	
	B	12.86 $\pm$ 7.70	13.11 $\pm$ 5.87	16.21 $\pm$ 9.30	16.36 $\pm$ 10.32	
2000	A	13.86 $\pm$ 7.67	4.05 $\pm$ 9.63	18.61 $\pm$ 8.91	17.35 $\pm$ 9.72	
	B	13.08 $\pm$ 8.65	14.80 $\pm$ 7.59	18.25 $\pm$ 9.72	17.02 $\pm$ 11.18	
2828	A	15.46 $\pm$ 8.43	11.09 $\pm$ 9.16	18.61 $\pm$ 5.02	17.35 $\pm$ 6.56	
	B	14.36 $\pm$ 7.45	10.74 $\pm$ 9.16	17.31 $\pm$ 10.39	16.93 $\pm$ 9.70	
4000	A	12.10 $\pm$ 7.89	13.73 $\pm$ 5.91	13.01 $\pm$ 9.18	13.92 $\pm$ 8.13	
	B	11.83 $\pm$ 6.43	11.73 $\pm$ 6.99	11.83 $\pm$ 8.40	13.77 $\pm$ 7.94	

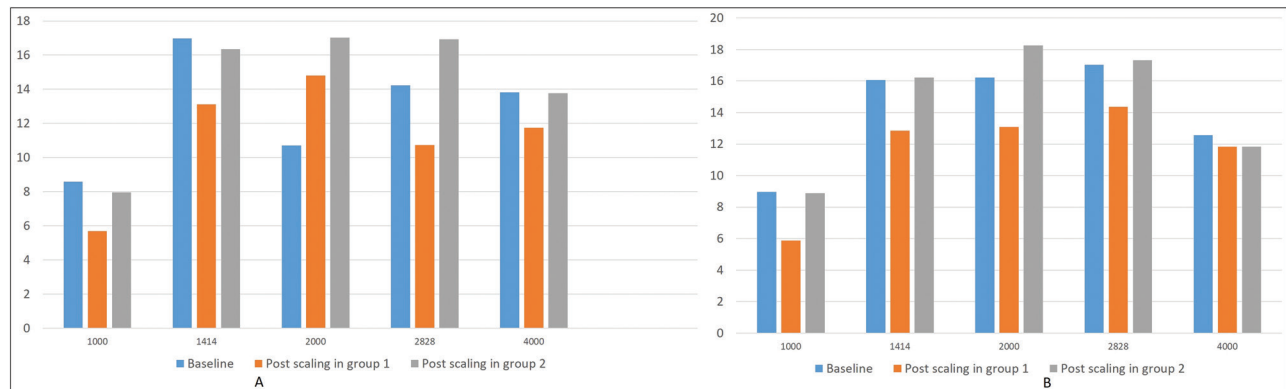


Figure 5: Comparison of the average post-scaling otoacoustics emission (OAE) readings of the left ear (A) and right (B) ear in both the groups compared with baseline [mixed-effects ANOVA at 90% confidence interval and $P < 0.042$; group 1: with no ear protection device (EPD) and group 2: with EPD]

both right and left ears in both the groups was done using mixed ANOVA at a 90% confidence interval and $P < 0.042$ [Table 4 and Figure 5].

DISCUSSION

Noise-induced hearing loss among dentists is one of the most common, yet ignored, occupational hazards.

Exposure to intense high-frequency noise in a dental setup has been linked with acute and chronic changes in the outer, middle, and inner ears.^[20,26-38] As these changes in the hearing threshold are impaired for early frequency, they are not noticed or diagnosed by the dentists until the permanent hearing loss sets in. A recent study in Flemish dentists observed that

there is a lack of knowledge and awareness among dentists and the need to increase the awareness of the consequences of OINHL among dentists. Al-Rawi *et al.* observed a positive correlation between the duration of dental service and the degree of hearing loss among dental professionals. Dental professionals with more than 10 years of experience and more than 8 h of daily work have the highest risk of developing hearing loss at frequencies ranging from 500 to 1600 Hz and tinnitus.^[38,52] Lopes *et al.*^[40] compared the hearing thresholds of general dentists, prosthodontists, and dental nurses using a high-frequency audiometric testing method and found that prosthodontists are the most affected group. Prosthodontists were the affected at the mean frequencies of 500–2,000 and 3,000–6,000 Hz, whereas the dental nurses were the most affected group at the mean high frequencies of 9,000 and 16,000 Hz. Al-Omouh *et al.*^[40,41] also reported a significant relationship between the degree of hearing impairment among dental assistants and the daily duration of exposure to dental occupational noise, followed by age. The authors also recommended screening guidelines and adapting hearing protection methods for dental professionals, particularly dental assistants and technicians. As most dental professionals work daily for more than 6 h in dental office and are exposed to noises from various dental equipment, they preclude to take any precautionary measures or actions to prevent the harmful effects of noise at work.

Many countries and organizations like the Occupational Safety and Health Administration of the United States Department of Labor have implemented legal standards regarding occupational noise exposure and noise-monitoring program when employees are exposed to noise equal to or exceeding 85 dB for more than 8 working hours.^[42–44] The OSHA also recommends the need to develop and implement surveillance programs and use noise cancellation devices at the dental workplace.^[32] A Cochrane review of 15 studies, including 79,986 participants, concluded that regular use of personal HPDs as part of a strong hearing loss prevention program is associated with less hearing loss.^[37] Groenewold *et al.*^[45] also compared the audiometric data from 19,911 workers who were exposed to significant noise and concluded that there is a significant increase in the risk for high-frequency threshold shift without the use of protective devices. HPDs can attenuate the noise by 15–28 dB when tested in a laboratory setting. A protective effect of 10–15 dB is relevant to a noise-exposed worker, as even a 10 dB attenuation will bring the noise levels to the acceptable range in more than 90% of the exposed individuals.^[21,28,37–43] However, implementation of noise conservation programs and use of EPDs among dentists

and dental-related personnel are not well adopted across the globe. This shows that either dentists are ignorant about the harmful effects of OINHL or they do not know how to prevent it. Therefore, it is extremely important that dentists acknowledge the presence of OINHL, evaluate their hearing acuity regularly, and use appropriate HPDs or EPDs while working.^[38] Although the awareness of hearing protection for dental auxiliary is gaining importance, the regular use of EPDs is not widely accepted.^[37]

Therefore, the present study aims to generate evidence and to evaluate how effective EPDs are in reducing the TTS exposure to noise from the ultrasonic scalers. The results of the study showed that the noise produced by the ultrasonic scalers can negatively impact the hearing acuity, especially for low threshold frequency. An increase in the PTA, acoustic reflex threshold, and reduced OAE values reflects the changes in the hearing threshold. This also shows that exposure to ultrasonic scaler even for a short duration can affect the overall hearing acuity. The change in the TTS immediately upon exposure to high-frequency noise is attributed to the protective involuntary unceasing contraction of the stapedius and tensor tympani muscles in the ears.^[46–53] This involuntary contraction of the ear muscles in response to high-frequency sound is known as an acoustic reflex or stapedial reflex. The increase in the acoustic reflex and middle ear pressure is reflected by the increased PTA and tympanogram readings.^[51] The onset of acoustic reflex facilitates the acclimatization of ears to the noisy environment, and therefore the detection of early hearing loss by dentists is difficult. However, a reduced OAE immediately after scaling is the most important and confirmatory finding that proves that a short-term exposure to high frequency after using the ultrasonic scalers can damage the cochlear cell of the inner ear.^[20,35–37]

Therefore, we conclude that dentists should mandatorily wear EPDs while working with instruments that emit high-frequency noise to prevent the TTS and subsequent development of ONIHL.^[16] The use of EPDs will prevent the development of TTS, which in long-term will prevent the risk of permanent hearing loss.^[10,26–28] EPDs can also reduce the risk of non-auditory effects of high-frequency noise such as fatigue, nausea, headaches, irritation, tinnitus, and even hypertension.^[37,38] Long-term benefits of wearing an HPD increase the work performance and work satisfaction.^[38,52] Thus, it is important to educate and spread the awareness among dentists regarding the importance of using EPDs and risk of OINHL from the dental workplace. Regular training and educational

program should be conducted to inform dentists regarding the importance of hearing protection and risk of ONIHL among them. The overall time in practice is also linked with increased hearing loss, and maintaining an optimal distance of 12 in. (30.48 cm) away from the noise source is recommended. However, the use of high-fidelity earplugs for noise cancellation is recommended for dentists and dental personnel, as they have acoustic filters that can cancel the noise more effectively and allow dentists to maintain effective communication with patients and colleagues. Additionally, it is important to note that the effectiveness of noise cancellation will depend on the quality of the material used, the motivation of the dentists to use the EPDs, physiological and anatomic characteristics of the user, correct placement, the duration of use, and overall noise level of the working environment.^[43,44]

There are two main types of EPDs that can be used: passive noise control and active sound control.^[39,40] Passive noise control devices such as earmuffs, disposable foam earplugs, and ear canal plugs work as physical barriers to sound.^[43-47] These HPDs are designed to be rolled into a thin cylinder and inserted in the ear canal where they expand to fit the user's ear canal.^[46,47] However, these EPDs may not be the best choices for dental practitioners as these devices muffle the sound of their own voice, but inhibit the ability of the practitioner to communicate with their clients.^[41-47] Additionally, they require specific training for proper fit and insertion. The active sound control devices, in contrast, are preferred as they can electronically modify sound transmission, reducing unwanted noise instead of blocking noise. These devices use hearing aid batteries, and they offer hearing protection from high-level sounds while allowing other sounds and communication with the patients. In addition, the electronic HPD can be disinfected and tends to fit better than the previously discussed options. A recent survey among dentists found that HPD is most preferred owing to its ease of use, comfort, feeling of openness, general pleasant appearance, and the ability to communicate with the client.^[43] Studies have shown that the effectiveness of hearing protection is close to 8 dB better, following instruction on the proper use of EPS when compared with no instruction or EPD.^[13-16] It is also shown that having the EPD correctly sized to a person's ear canal results in higher usage of the device.^[49] Learning the proper insertion techniques and application of EPD will improve the protection provided from these devices.^[24,54]

If specific noise cancellation devices are not available, a cotton ball saturated with a lubricant such as olive

oil can be temporarily placed into the ear canal.^[49] Furthermore, dentists should adopt a healthy working environment to prevent the development of ONIHL. For example, the duration of each dental procedure should be controlled, and a good rest period between successive noise exposures should be given to facilitate recovery of the TTS.^[39] Dentists should plan their daily work schedule and set their permissible duration of exposure depending on the maximum frequency of noise exposure. According to the OSHA, the maximum daily tolerable duration of exposure to noise with a frequency of 90 dB is 8 h. For noise above 90 dBA, the exposure time must be reduced by 50% for every 5 dB increase (e.g., 93 dB is 4 h; 96 dB is 2 h; 99 dB is 1 h; 102 dB is 30 min; 105 dB is 15 min).^[3] This adjustment in the noise exposure is referred to as the 5 dB trading rule or 5 dB exchange rate. Moreover, as the left ear is more commonly affected with higher STS when compared with the right ear, dentists need to maintain optimal chair positions (a minimum of 30 cm) while treating patients. The operating handpiece should also be well maintained, as old and poorly maintained equipment emits sound waves of higher intensity. In order to decrease the prevalence of hearing loss among dental professionals, the noise levels generated by the high-speed handpieces should be below 65 dB(A) and should never exceed 80 dB(A).^[49] Since then, the noise levels produced by new dental equipment are generally below 85 dB(A).^[47-50] However, it must be noted that aged or worn dental equipment could still produce noise levels exceeding 85 dB(A).^[51] Apart from the development and appropriate maintenance of dental equipment, a common consensus on decreasing the prevalence of hearing loss is to promote the use of protective measures. Some studies reported that there was slight or no hearing loss among dentists, if control measures, including protective measures, were strictly implemented.^[48] It is also essential that dentists undergo regular monitoring of their overall noise exposure and undergo regular audiometric testing to detect the presence of temporary hearing loss at an early stage. The threshold shift measured through audiometric testing is the most acceptable method of detecting the influence of noise exposure on the cochlear mechanism.^[32]

Based on these results, regulatory body should advise dental professionals to mandatorily wear EPDs and undergo regular self-monitoring of noise exposure and hearing acuity. This could improve the effectiveness of hearing conservation programs and prevent permanent ear damage from harmful effects of noise in the dental workplace.^[12,54] Additionally, further research

along with comprehensive educational programs and workshops should be urgently conducted for dentists to spread awareness regarding the importance of EPDs and methods of prevention of ONIHL. Further research should evaluate and compare the effects of different types of EPDs on OINHL among dentists to gauge the best type of EPD that can be worn by dentists and dental personnel to prevent ONIHL. Special training and workshops should be organized by various dental bodies to spread the awareness among dental practitioners regarding the risk of OINHL and to teach the importance of EPD and how it can be used to protect their hearing acuity.^[13-16]

CONCLUSION

ONIHL is an inevitable and serious occupational hazard among dentists. The noise in the dental workplace can induce TTS and reduce our hearing acuity, with left ear more commonly affected than the right ear. Hence, noise cancellation device or EPDs should be worn by all dental practitioners to prevent the harmful effect of noise on the auditory and non-auditory symptoms. EPDs can prevent shift in the hearing threshold and changes in the stapedial reflex and reduce the OAEs from the inner ears. Like the use of personal protective equipment, the use of EPDs should become a mandatory dental practice to prevent the harmful and unavoidable effect of noise in the dental workplace and development of ONIHL among dentists.

ACKNOWLEDGEMENT

Kishan M. Mohan: concept; design of the study, collection of data, analysis of data, writing the manuscript, proof reading the manuscript. Aditi Chopra: Concept; design of the study, collection of data, analysis of data, tables and figures; writing the manuscript, proof reading the manuscript. Vasudeva Guddattu: Statistical analysis of data, tables and figures; writing the manuscript, proof reading the manuscript. Shruti Singh: Concept; design of the study, collection of data, analysis of data, tables and figures; writing the manuscript, proof reading the manuscript. Kumari Upasana: Preparation of tables and figures; writing the manuscript, referencing the paper, proof reading the manuscript.

FINANCIAL SUPPORT AND SPONSORSHIP

Nil.

CONFLICTS OF INTEREST

There are no conflicts of interest.

AUTHORS' CONTRIBUTION

Not applicable.

ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted by approving the Kasturba Medical College and Hospital with Institutional Review Committee IEC no.: 323/2017 and registered at the Clinical Trials registry with No. CTRI/2017/07/009031 registered on 12/07/2017.

PATIENT DECLARATION OF CONSENT

Not applicable.

DATA AVAILABILITY STATEMENT

The data set used in the current study is available on request from Dr. Aditi Chopra (aditi.chopra@manipal.edu).

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