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Effects of Drilling in Mastoid Cavity over Hearing in the Contralateral Ear

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Abstract

In advanced otological surgeries, powered instruments form an indispensable part. The risk of deterioration to hearing in the operated ear is a commonly discussed issue, however, there remains a possibility of affecting the hearing in the contralateral ear due to transcranial vibration. So in this study we aimed to assess the possibility of the non-operated ear being affected by the noise generated during ear surgeries and whether it is temporary or permanent in nature. **Methodology:** This study included 63 patients diagnosed with unilateral disease who underwent mastoid surgery. Preoperatively all the patients were subjected to Pure tone audiometry (PTA), Transient evoked otoacoustic emission (TEOAE) and Distortion product otoacoustic emission (DPOAE). Patients were operated using both cutting and diamond burrs of ranging from sizes 1 - 6 mm. Total drilling time was recorded. **Results:** Postoperative hearing evaluation was done at 1 week, 4 weeks and 12 weeks. The sound emitted by various burrs was recorded by Sound Level Meter. Out of the total 58 patients that followed up, 46 showed change in at least one of the hearing parameters. Patients showing changes had a higher drilling time as compared to those with no changes. Of these, the changes associated with the total drilling time and with cutting burr time were found to be significant. The hearing changes seen on PTA, TEOAE and DPOAE were transient in nature with only one patient having a persistent decreased high frequency threshold at the end of 12 weeks. It was also found that cutting burrs produce more sound as compared to diamond burrs and a larger size burr of a type produces more sound than a smaller one of its type. **Conclusion:** The drilling of mastoid bone during ear surgeries can transiently impair the hearing in the contralateral ear which is of great significance in patients with only one hearing ear.

Keywords

Mastoid Drilling, Affected Hearing, Contralateral Ear Damage

1. Introduction

In advanced otological surgery involving newer powered instruments, which forms an indispensable part of surgical ornamentum, one wonders if there is a negative side to this advancement like in any other aspect of life. Surgeries involving the mastoid cavity, like cortical mastoidectomy, modified radical mastoidectomy and radical mastoidectomy, have been employed for over 300 years to control suppurative diseases of ear, but the first proposed mastoidectomy dates back more than four centuries.

Mastoidectomy did not become part of otological practice until about 1870. In 1873 Schwartze and Eysell reported use of cortical mastoidectomy for management of acute mastoid infections [1]. Zaufal expanded the concept of cortical mastoidectomy and, in 1890, described the radical mastoidectomy [2]. The operation was accomplished using mallet and gouges. These tools remained the standard equipment and were used with remarkable finesse until Lempert popularised the use of a drill and loupe magnification in the 1920s. With the introduction of the Zeiss operating otologic microscope in 1953 and the description of the canal-wall-up mastoidectomy by Jansen shortly thereafter, the paradigm for mastoid surgery changed dramatically for acute and chronic mastoid infections [3] [4].

Exposure to a short time, high-intensity noise can cause either temporary or permanent hearing loss (HL). Bone drilling is an essential part of otological surgeries and the drill-generated noise during ear surgeries, as well as surgical trauma, has been shown as a cause of sensorineural hearing loss in the operated ear [5]. The possible contribution of drill-generated noise during tympanomastoid surgery to postoperative sensorineural hearing loss is in excess of 100 dB [6]. The amount of energy transmitted to the cochlea depends on the noise levels produced and the duration of exposure [7] [8]. The effect of drill-induced trauma on the cochlea in ear surgery has been investigated previously using pure tone audiometry (PTA) [9], high frequency audiometry [10], otoacoustic emissions (OAEs) [11] [12], and electrocochleography [13]. One of main causes of high frequency sensorineural hearing loss observed after tympanomastoid surgeries is accidental drilling on the ossicular chain which results in damage to the operated ear by the mechanism of acoustic trauma [14] [15].

Dan *et al.* (2007) reported in their study that drilling on the intact ossicular chain produces a vibratory force which is similar to the noise levels known to cause acoustic trauma leading to inner ear structure damage [14]. This mechanism causes temporary threshold shift (seen in high frequency range of 2 - 4 kHz), which is resolved by the time of unpacking of the ear [16] [17]. Mislav *et al.* (1997) described permanent sensorineural hearing loss which occurred if there was inadvertent contact with intact ossicular chain while drilling [18]. It reported that touching the intact ossicular chain with burrs produces a pressure which when conducted towards the footplate is comparable to 130 to 150 dB sound pressure levels producing changes in organ of corti with disruption of cytoarchitecture and cellular degeneration mostly seen in the outer hair cells [19].

As in the case of the diseased ear, the normal hearing status of the contralateral ear is of great importance, and there remains a distinct possibility of affecting the hearing in the contralateral ear. This analysis is very important as contralateral hearing is often thought to be unaffected during surgery on the other ear. The contralateral ear is subjected to the drill noise, but the effect of drill-generated noise on the non-operated ear has been discussed even less. It has been described that both the ears are exposed to acoustic trauma due to noise generated by the use of otological drill to the extent of 90 dB, difference being only 5 - 10 dB less in non-operated ear [5] [20] [21] [22] [23]. A drill-induced noise is transmitted to the non-operated ear in two ways: Through the skull and around the ear [8]. Vibration of temporal bone may have implications leading to cochlear damage, and both drill and suction generated noise and vibration may have additive effect in damaging the cochlea. Cutting burr has been described to produce more noise as compared to diamond burr [5] [22] [23] [24]. Other variables such as rotation speed of burr, type of burr, burr size and site of drilling have also been investigated in isolated temporal bones, cadavers and animal model [5]. Heat generated by the rotating burr specially while drilling near the vestibule has been reported to cause sensorineural hearing loss. The variations in drill parameter and the duration of drilling have been described to determine the extent of noise, vibration and heat generation [5] [22] [23] [24]. Pye and Ulehlova reported that intense noise caused drastic changes, initially in the first row of outer hair cells, followed by inner hair cells, and then the change spread to all rows in the affected area [25]. As outer hair cells are the initial target of noise induced cochlear damage [26], it seems logical to assess hearing in the normal contralateral ear using OAEs (otoacoustic emissions) and audiometry.

Few studies show a temporary hearing loss or threshold shift in a normal contralateral ear due to drilling in the opposite diseased ear. However, this can be of extreme importance in cases of susceptible individuals like those on ototoxic drugs or in patients in whom the contralateral ear is the only hearing ear. So, in this study, we aimed to assess the possibility of the non-operated ear being affected by noise and vibration-induced trauma leading to cochlear damage during ear surgeries and whether it is temporary or permanent in nature.

2. Aims and Objectives

1) To understand the effect of high intensity noise associated with drilling on hearing in contralateral ear and to establish whether it is temporary or permanent in nature;

2) To establish the relation between duration of drilling and hearing loss, if any.

Noise trauma due to otologic drilling

The exposure of the ear to noise is a well-known factor which can cause sensorineural hearing loss (SNHL). In otology, a wide variety of devices are used that generate significant noise. Noise levels range from 120 - 122 dB during drilling of the cortical bone and from 117 - 121 dB while drilling the mastoid cavity [24]. Exposure to this noise during ear surgery can thus result in acoustic trauma [27]. Drill generated noise has been incriminated as a cause of SNHL in the operated ear [8]. With advancing technology and introduction of increasing high speed drills for mastoid surgeries the risk of cochlear damage may be present in both the operated and non-operated ear. When a drill is used during mastoid surgery, the ipsilateral cochlea is exposed to noise levels of about 100 dB and the contralateral cochlea is exposed to levels of 5 - 10 dB lower [22].

Drill induced noise is transmitted to the non-operated ear in two ways: through the skull and around the ear [9], with minimal inter-aural attenuation [20]. The drill not only produces noise, but also generates strong vibration, transmitting oscillations into both the cochleae thereby amplifying the damage. [9] Noise exposure leads to dysfunction of the outer hair cells, which may produce a temporary hearing loss in ipsilateral or opposite ear [9] [10]. Drill generated noise levels and the exposure time interval determines the level of hearing loss. In mastoid surgeries, higher levels of noise induced hearing losses are expected due to longer duration of drilling involved [28]. Use of drilling during mastoid surgeries causes NIHL specially when used on or near to the ossicular chain and stapes footplate.

Noise levels are higher with larger burrs, and with cutting burrs as compared to diamond burrs. Rotation speed and site of drilling do not seem to influence the noise levels [5]. There are only a few studies describing the effect of touching the ossicular chain with a rotating burr upon stapes vibration. Helms found that touching the intact ossicular chain with a rotating burr produced pressures conducted to the stapes footplate comparable to 130 dB SPL [29]. Pau and his colleagues showed that contacting the tympanic membrane with the drill can cause a vibration comparable to 150 dB SPL [30]. One of the principal factors affecting the noise level during drilling is the diameter of the burr, with the larger diameter burr producing greater vibratory force. This effect is particularly obvious with the use of a cutting burr. One cause for this increase in noise level could be due to contact area between the burr and the incus, with more energy being transmitted to the ossicular chain through a larger contact area.

One point to ponder over is, if it is possible to prevent acoustic trauma due to accidental contact of the burr on the ossicular chain while drilling during course of surgery. Simple disarticulation of the long process of the incus does not appear to offer any protection in animal studies. There have been two studies that have investigated the possible protective effects of steroids. In the first study—placebo-controlled, randomized, blinded study, intra-peritoneal injection of methylprednisolone in guinea pigs showed no protective effect in reducing or improving the auditory threshold shifts caused by drill-induced injury to the body of the incus [31]. In the second guinea pig study, intratympanic injection of methyl-prednisolone significantly improved drill-induced sensorineural hearing loss as measured by otoacoustic emissions [32]. However, other studies have shown some promising results with oral magnesium supplements and calcium antagonist drugs [33].

Cutting burrs produces more high frequency than lower frequency vibratory energy. Caution is therefore mandatory during drilling around an intact ossicular chain to avoid a permanent sensorineural hearing loss as disarticulation of the incudostapedial joint prior to drilling may have no protective value. Trauma due to drilling cannot be totally avoided as it is a part and parcel of otological procedures however caution can be and should be taken.

As seen in the study by Kylen *et al.* [5], the noise produced by the diamond burrs is lower as compared from that of the cutting burrs. The mean noise levels of the diamond burrs are 5 - 11 dB lower than that of the cutting ones. Also, smaller the burr, the lower the noise. The sound emitted by drilling in mastoid surgeries cannot be avoided however it can be minimised by proper selection of burr type and size. Also avoiding unnecessary contact of drill to the ear during mastoid surgeries can help minimise the acoustic trauma and the related effects on hearing in both the operated and non-operated ear.

3. Materials and Methods

This prospective study was conducted on 63 patients visiting the Out-Patient Department (OPD) of Otorhinolaryngology at Goa Medical College which is a tertiary care hospital. The study was carried out over a period of one and a half years between Nov 2014-April 2016. All the patients included in the study were diagnosed with unilateral chronic otitis media and underwent mastoid surgery which included cortical mastoidectomy, modified radical mastoidectomy and radical mastoidectomy. The patients had a normal contralateral ear on otoscopy and audiological examination.

A detailed history was taken and a thorough clinical examination was performed on all the patients. An informed consent was obtained from all patients. Preoperatively all the patients were subjected to appropriate investigations including Pure tone audiometry (PTA), Transient evoked otoacoustic emission (TEOAE) and Distortion product otoacoustic emission (DPOAE). PTA was performed using Arphi diagnostic audiometer 2001 and bone and air conduction audiometric thresholds were recorded at 0.25, 0.5, 1, 2, 4 and 8 kHz.

Bone conduction threshold of more than 20 dB at any frequency was considered abnormal. TEOAE and DPOAE were recorded using ER-34 ERO.SCAN OAE test system (version 7.65.01).

Patients were operated by different surgeons and both types of burrs-cutting and diamond of various sizes ranging from 1 - 6 mm were used during mastoidectomy for drilling. Total drilling time was recorded by the assisting surgeon with the help of nurses or anaesthetists.

Post-operative hearing evaluation was done by PTA, DPOAE and TEOAE at an interval of 1 week, 4 weeks and 12 weeks and hearing loss was calculated using the average at speech frequencies of 500 Hz, 1 kHz and 2 kHz for analytical purposes.

The sound emitted by various sizes and types of burrs was recorded by Sound Level Meter: Cygnet 2021, which was calibrated on the Sound Level Calibrator (Quest) for 94 dB by N.P.K Founders Pune (Test & Calibration Lab Division).

The data was compiled and analysed using student t test.

The study was approved by institutional ethical committee.

4. Results

4.1. Sex Distribution

There were total 63 patients in this study of which 30 were males and 33 were females. Males constituted for 41% of the total whereas females constituted the remaining 51%. Of the total patients 4 males and 1 female were lost to follow up and were excluded from the study. There were more number of females in this study as compared to males as shown in Table 1 and Figure 1.

4.2. Age Distribution

The study comprised of patients in the age groups of 5 - 65 years. The maximum number of patients were in the age groups of 10 - 20 years (28.6%) followed by 20 - 30 years (25.4%). The least number of patients were in the age groups of 60 - 70 years (3.2%) followed by 50 - 60 years (4.8%) as shown in Table 2 and Figure 2.

4.3. Association of Total Drilling Time with Changes in Hearing Parameters (PTA, DPOAE, TPOAE)

Of the total 58 patients that followed up in the study, 46 patients showed change

Table 1. Sex distribution in study population.

PATIENTS	n (%)
MALES	26 (45%)
FEMALES	32 (55%)

n = Number of patients; (%) = Percentage of patients.

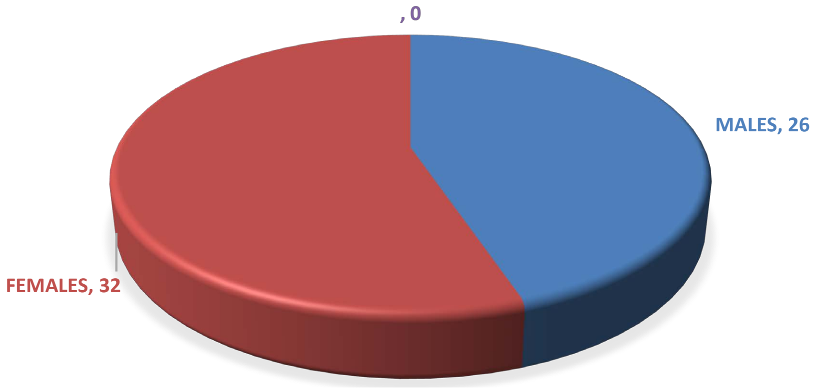

Figure 1. Pie chart of sex distribution in study population.

Table 2. Age distribution in study population.

AGE GROUP	TOTAL n (%)	FEMALES n (%)	MALES n (%)
0 - 10	5 (7.9%)	2 (6.7%)	3 (9.1%)
10 - 20	18 (28.6%)	10 (33.3%)	8 (24.2%)
20 - 30	16 (25.4%)	4 (13.3%)	12 (36.4%)
30 - 40	9 (14.3%)	4 (13.3%)	5 (15.2%)
40 - 50	10 (15.9%)	8 (26.7%)	2 (6.1%)
50 - 60	3 (4.8%)	1 (3.3%)	2 (6.1%)
60 - 70	2 (3.2%)	1 (3.3%)	1 (3.0%)

n = Number of patients; (%) = Percentage of patients.

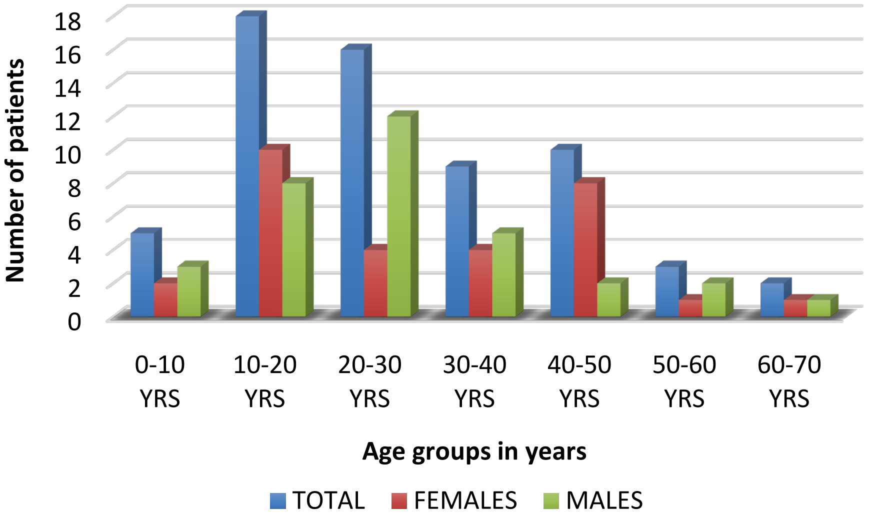

Figure 2. Bar diagram of age distribution in study population.

in at least one of the hearing parameters—PTA, DPOAE and TEOAE. Patients showing changes in hearing parameters had a total, diamond and cutting burr mean drilling time of 57.03, 19.74 and 37.29 minutes respectively. However, patients not showing any changes had a lesser mean drilling time of each total, diamond and cutting burr of 43.64, 16.04 and 27.60 minutes respectively as shown in Table 3 and Figure 3.

4.4. Hearing Loss as Assessed by PTA Associated with Drilling Time

Of the total 58 patients 32 patients showed hearing loss as assessed by PTA readings over 12 weeks. Patients showing hearing loss had a mean drilling time of 61.11, 20.55 and 40.57 minutes of total, diamond and cutting burr respectively. However, patients without any hearing loss had a lesser mean drilling time of 48.69, 17.70 and 30.99 minutes in total, diamond and cutting burr respectively as shown in Table 4 and Figure 4.

Table 3. Presence of change in hearing parameters in association with drilling time.

Duration of drilling with type of burr	Changes in hearing as measured by PTA, DPOAE, TEOAE	n (%)	Mean drill time (min)	p value
Total	No	12 (20%)	43.64	0.002 **Significant**
	Yes	46 (80%)	57.03	
Diamond	No	12 (20%)	16.04	0.103 Not significant
	Yes	46 (80%)	19.74	
Cutting	No	12 (20%)	27.60	0.005 **Significant**
	Yes	46 (80%)	37.29	

n = Number of patients; (%) = Percentage of patients.

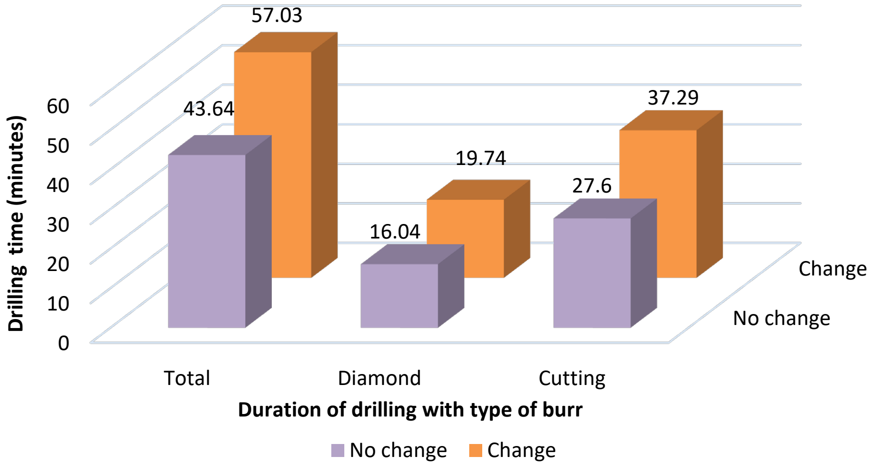

Figure 3. Presence of change in hearing parameters in association with mean drilling time.

Table 4. Hearing loss as assessed by PTA associated with drilling time.

Duration of drilling with type of burr	Presence of hearing loss as assessed by PTA	n (%)	Mean drill time (min)	p value
Total	No	32 (55%)	48.69	0.153 Not significant
	Yes	26 (45%)	61.11	
Diamond	No	32 (55%)	17.70	0.915 Not significant
	Yes	26 (45%)	20.55	
Cutting	No	32 (55%)	30.99	0.047 Significant
	Yes	26 (45%)	40.57	

n = Number of patients; (%) = Percentage of patients.

4.5. DPOAE and Drilling Time

Of the total 58 patients 42 patients had a referred DPOAE readings over 12 weeks and had a mean drilling time of 57.14, 19.79 and 37.35 minutes of total, diamond and cutting burr respectively as compared to patients with pass DPOAE who had a lesser mean drilling time of 46.70, 16.84 and 29.87 minutes in total, diamond and cutting burr respectively as shown in Table 5 and Figure 5.

4.6. TEOAE and Drilling Time

Of the total 58 patients 40 patients showed referred TEOAE readings over 12 weeks had a mean drilling time of 57.42, 19.78 and 37.64 minutes of total, diamond

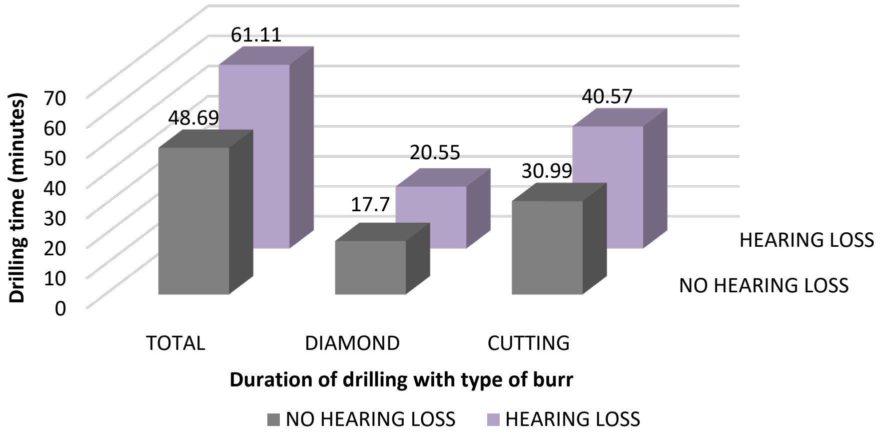

Figure 4. Presence of hearing loss as assessed by PTA in association with mean drilling time.

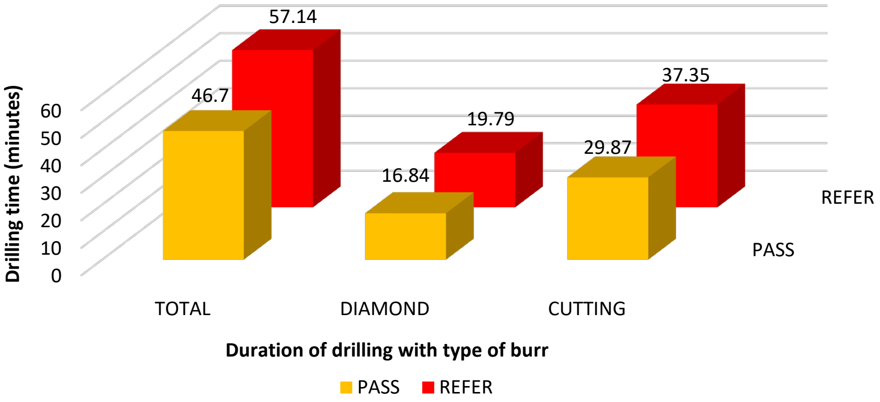

Figure 5. DPOAE and mean drilling time.

Table 5. DPOAE and drilling time.

Duration of drilling with type of burr	DPOAE (REFER/PASS)	n (%)	Mean drill time (min)	p value
Total	PASS REFER	16 (28%) 42 (72%)	46.70 57.14	0.194 Not significant
Diamond	PASS REFER	16 (28%) 42 (72%)	16.84 19.79	0.243 Not significant
Cutting	PASS REFER	16 (28%) 42 (72%)	29.87 37.35	0.205 Not significant

n = Number of patients; (%) = Percentage of patients.

and cutting burr respectively as compared to patients with pass TEOAE who had a lesser mean drilling time of 47.23, 17.18 and 30.05 minutes in total, diamond and cutting burr respectively as shown in Table 6 and Figure 6.

4.7. Post Operative Hearing Loss at Speech Frequencies

In the first postoperative week a mean loss of 22.91 dB in bone conduction was observed in 23 patients. Two patients however developed loss in air conduction with mean of 14.50 dB.

In the fourth postoperative week mean loss in bone conduction was observed to be 18.55 dB in 9 patients.

In the twelfth postoperative period only one patient had a high frequency dip in bone conduction of 15 dB as shown in Table 7 and Figure 7.

4.8. Pre and Post Operative DPOAE

Of the 58 patients, 41 patients developed referred in DPOAE in the 1st week of postoperative period. The number of patients with referred DPOAE reduced in 4th post-operative week to 23. By end of 12 weeks only 1 patient had an abnormal DPOAE and rest of the patients with changes in previous follow-ups had returned to normal as shown in Table 8 and Figure 8.

Table 6. TEOAE and drilling time.

Duration of drilling with type of burr	TEOAE (REFER/PASS)	n (%)	Mean drill time (min)	p value
Total	No	18 (31%)	47.23	0.147
	Yes	40 (69%)	57.42	Not significant
Diamond	No	18 (31%)	17.18	0.243
	Yes	40 (69%)	19.78	Not significant
Cutting	No	18 (31%)	30.05	0.177
	Yes	40 (69%)	37.64	Not significant

n = Number of patients; (%) = Percentage of patients.

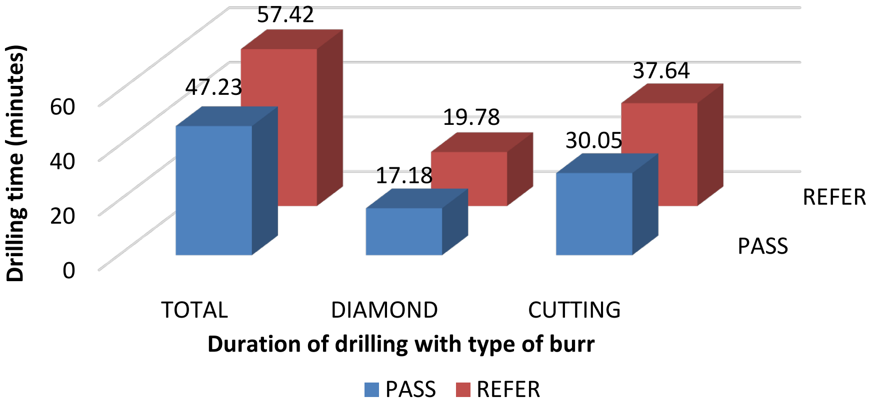

Figure 6. TEOAE and mean drilling time.

Table 7. Number of patients with post-operative hearing loss at speech frequencies at various follow up intervals.

HEARING LOSS	1 WEEK n (%)	4 WEEKS n (%)	12 WEEKS n (%)
ABSENT	25 (43%)	9 (15%)	1 (2%)
PRESENT	33 (57%)	49 (85%)	57 (98%)

n = Number of patients; (%) = Percentage of patients.

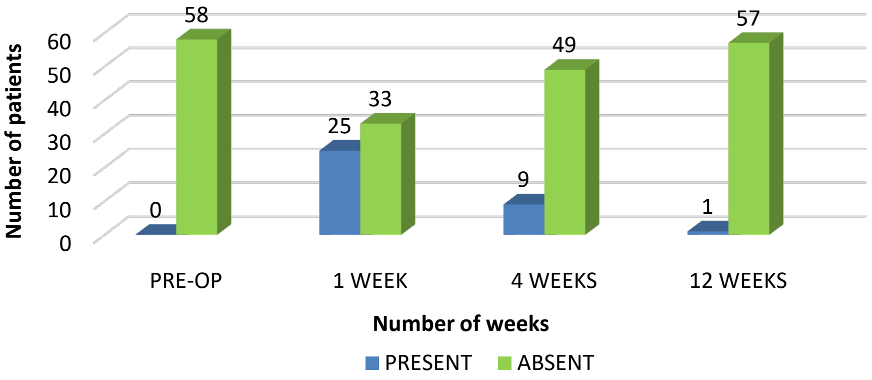

Figure 7. Number of patients with post-operative hearing loss at speech frequencies.

Table 8. Number of patients with DPOAE changes at various post-operative follow up intervals.

DPOAE	1 WEEK n (%)	4 WEEKS n (%)	12 WEEKS n (%)
REFER	41 (71%)	23 (40%)	1 (2%)
PASS	17 (29%)	35 (60%)	57 (98%)

n = Number of patients; (%) = Percentage of patients.

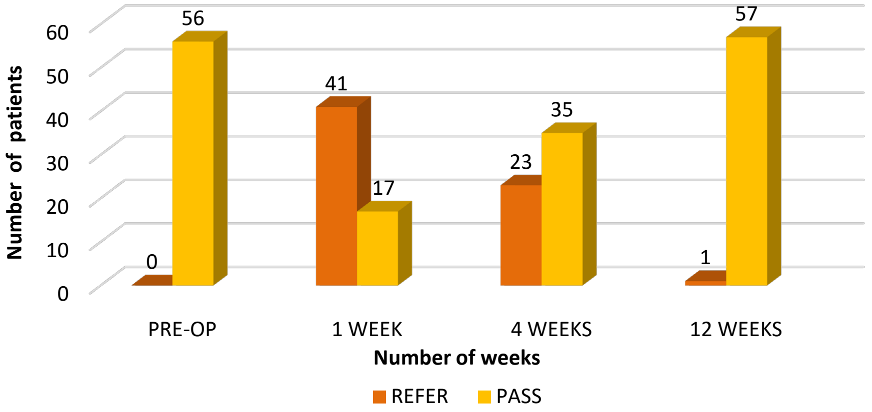

Figure 8. Number of patients with DPOAE changes (refer/pass) in post-operative period.

4.9. Pre and Post Operative TPOAE

Of the 58 patients, 38 patients developed change (refer) in TEOAE in the 1st week of postoperative period.

The number of patients with referred TEOAE reduced in 4th post-operative week to 20.

By end of 12 weeks however, only 1 patient had an abnormal TEOAE and rest of the patients with changes in previous follow-ups had returned to normal as shown in Table 9 and Figure 9.

5. Discussion

The ear is an essential component in hearing and hence plays an important role in communication system in human beings. So, it is important to protect the ears from any form of injury-one of them being noise induced hearing loss.

Bone drilling is an essential part of these otological surgeries and the drill-generated noise during ear surgery, as well as surgical trauma, has been shown as a cause of sensorineural hearing loss in the operated ear [5]. The use of drill has been reported to generate noise to the extent of 90 - 100 dB [6], therefore, drilling during temporal bone surgery may result in temporary or permanent noise-induced hearing loss or tinnitus. This has significant implications for the patients. The amount of energy transmitted to the cochlea depends on the noise levels produced and the duration of exposure [7] [8].

The non-operated ear is also subjected to the drill noise and there is only a 5 - 10

Table 9. Number of patients with TEOAE changes at various post-operative follow up intervals.

TPOAE	1 WEEK n (%)	4 WEEKS n (%)	12 WEEKS n (%)
REFER	38 (66%)	20 (34%)	1 (2%)
PASS	20 (34%)	38 (66%)	57 (98%)

n = Number of patients; (%) = Percentage of patients.

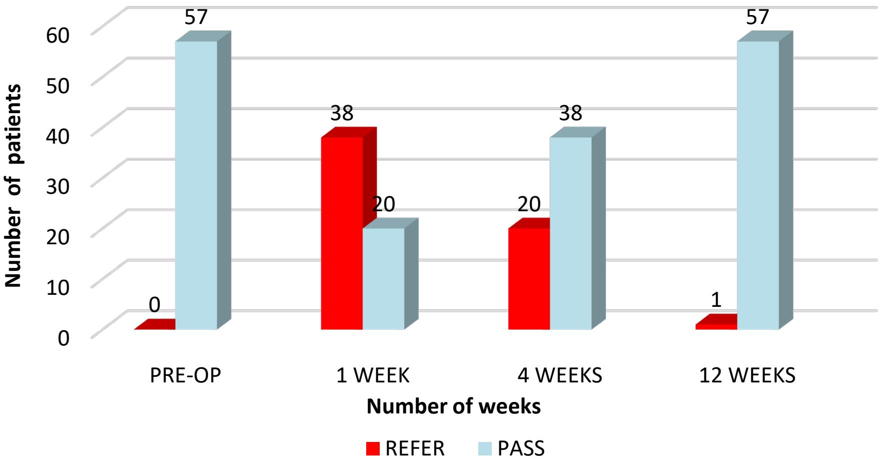

Figure 9. Number of patients with TEOAE changes (refer/pass) in post-operative period.

dB decrease in noise intensity on the contralateral side [20] [21]. A drill-induced noise is transmitted to the non-operated ear in two ways: Through the skull and around the ear [8]. Drilling has been shown to cause acoustic trauma hence longer durations are responsible for more harm to the hearing parameters. Tos *et al.* reported no significant change in postoperative hearing status in the normal contralateral ear in 50 cases of translabyrinthine removal of acoustic neuromas [34]. This could be explained by the fact that except for the cortical mastoidectomy, the predominant part of the surgery was carried out using a small (1 - 4 mm) diamond burr. As seen in the study by Kylen *et al.* [5], the noise produced by the diamond burrs is lower as compared from that of the cutting burrs. The mean noise levels of the diamond burrs are 5 - 11 dB lower than that of the cutting ones. Also, smaller the burr, the lower the noise. In the study by Tos *et al.*, surgery was predominantly carried out using a small diamond burr; which would not have generated a noise sufficient enough to cause damage to the contralateral ear. Secondly, Tos *et al.* evaluated hearing using pure tone and speech audiometry three months after the surgery. Thus, the detection of a temporary threshold shift was unlikely.

The present study had more number of females as compared to males. The maximum number of patients in the study were young and were in the age groups of 10 - 30 years accounting for almost 59% of the total study population. This observation can be attributed to the fact that there is more awareness about health issues in younger population and that they seek available health services in order to get treated and to stay healthy.

In this study, of the total 58 patients 46 patients showed change in atleast one of the hearing parameters *i.e.* PTA, DPOAE and TEOAE.

Patients showing changes had a total, diamond and cutting burr mean drilling time of 57.03 ± 10.04, 19.74 ± 6.86 and 37.29 ± 7.53 minutes respectively. However, patients not showing any changes had a lesser mean drilling time of each total, diamond and cutting burr of 43.64 ± 3.56, 16.04 ± 2.07 and 27.60 ± 3.63 minutes respectively. Of these, the changes associated with the total drilling time and with cutting burr time were found to be significant with p values of 0.002 and 0.005 respectively. Changes associated with diamond burr drilling time were found to be insignificant.

Of the total 58 patients 32 patients showed hearing loss as assessed by average of speech frequencies over 12 weeks and had a mean drilling time of 61.11 ± 9.32, 20.55 ± 4.90 and 40.57 ± 7.57 minutes of total, diamond and cutting burr respectively. However, patients without any hearing loss had a lesser mean drilling time of 48.69 ± 8.06, 17.70 ± 7.14 and 30.99 ± 5.20 minutes in total, diamond and cutting burr respectively.

Of these changes the ones associated with cutting burr drilling time were found to be significant with a p value of 0.047 whereas those with total and diamond burr time were found to be insignificant.

In the first postoperative week a mean loss of 22.91 dB in bone conduction was observed in 23 patients. Any loss in bone conduction of more than 20 dB was taken as significant. Two patients however developed conductive hearing loss with mean air-bone gap of 14.50 dB. The two patients that developed a conductive hearing loss, had a normal PTA by the end of 4 weeks. However, we are unable to explain the conductive hearing loss seen in two patients and it may be attributed to recently developed Eustachian tube pathologies but there was no history or clinical finding suggestive of the same.

In the fourth post-operative week mean loss in bone conduction was observed to be 18.55 dB in 9 patients. In the twelfth postoperative period only one patient had a high frequency dip in bone conduction of 15 dB. Gowda *et al.* reported transient hearing loss recorded as high frequency sensorineural hearing loss, which resolved by the end of 1st month in the post-operative period [35]. However, study conducted by Goyal *et al.* did not find any significant changes in post-operative PTA [36]. In the present study 71% patients had referred DPOAE (distortion product otoacoustic emissions) in the 1st week of postoperative period. Patients with referred DPOAE reduced in 4th post-operative week to 40%.

By end of 12 weeks only one patient had a referred DPOAE and rest of the patients with refer DPOAE in previous follow-ups had returned to normal *i.e.* pass. It reflects that the changes produced by drilling in DPOAE are transient and not permanent in nature. Similarly, 66% patients developed referred TEOAE in the 1st week of postoperative period which reduced in the 4th post-operative week to 35%. By end of 12 weeks however, only one patient had a referred TEOAE and rest of the patients with changes in previous follow-ups had returned to pass TEOAE.

Similar results have been reported in studies by Hegewald [11] and Schick [17]. Da Cruz *et al.* have also described transient reversible changes [28]. Studies have reported that Spontaneous OAE, Transient evoked OAE and Distortion product OAE were affected in the contralateral ear in the immediate post-operative hours, but were regained by 96 hours in the post-operative period to pre-operative amplitude levels [13]. Paksoy *et al.* [37], Domenech *et al.* [15], Desai *et al.* [38], and Palva *et al.* [39], concluded that patients who developed sensorineural hearing loss after mastoidectomy had a high frequency loss. Karatas *et al.* concluded that mastoid drilling caused transient hearing loss in the contralateral normal hearing ear, which recovered spontaneously within 72 - 96 hours postoperatively [13]. However, Migirov *et al.* [40] and Karimi *et al.* [41] demonstrated in their study that this loss, though reversible, could last for a period of more than 1 month. Gowda *et al.* also reported transient changes in PTA recorded as high frequency sensorineural hearing loss, which resolved by the end of 1st month in the post-operative period [35]. Mustafa Paksoy *et al.* concluded with their retrospective analysis of mastoidectomy patients that, they developed a loss of about 5 dB in their bone conduction threshold levels [37]. Zou J *et al.* have also shown that hearing in either the operated or contralateral ear may be temporarily affected by mastoid drilling [42]. In contrast to the present study, some studies found SNHL in the operated ear but no changes in hearing in the contralateral ear [8].

In present study, like most other studies, the hearing changes seen were transient in nature which resolved by the end of 12 weeks in the post-operative period. Previous studies have evaluated hearing loss in both high and low frequencies separately however, this is a limited study that accounted for either high or low or both high and low frequency changes in the post-operative period and the results were not segregated into high and low frequencies for analysis. In present study one patient had a persistent decreased high frequency threshold at the end of 12 weeks but it needs longer follow up beyond 12 weeks to label it permanent in nature.

Also in our study, by using the sound-pressure meter we found, as proven by previous studies [5], that cutting burrs definitely produce more sound upto 83 dB as compared to diamond burrs that produces a sound of about 81 dB. A larger size burr of a type (cutting or diamond) produces more sound than a smaller one of its type. One cause for this increase in noise level could be due to contact area between the burr and the incus, with more energy being transmitted to the ossicular chain through larger contact area.

Though noise induced hearing loss associated with drilling is transient in nature, it should be given due consideration, especially in cases with non-operated ear being the only hearing ear or with impaired non-operated ear. This acoustic trauma if cannot be completely avoided, can at least be minimised by proper surgical technique. Hence, selecting the right size and type of burrs and reducing the operating time and thereby the duration of exposure of the cochlear structures to noise is recommended to help minimize damage in case of patients with contralateral ear being the only hearing ear.

6. Conclusion

The drilling of mastoid bone during ear surgeries produces high levels of noise which impairs the hearing in the contralateral *i.e.* non-operated ear though transiently. Longer durations of drilling increase the chance of developing changes in hearing parameters. Although the duration cannot be minimised, care can be taken while drilling to avoid unnecessary contact of drill with the ear. Larger sized burrs produce more sound than smaller ones. Cutting burrs produce more sound than the diamond burrs and hence have a potential to cause more damage. Although drilling produces temporary changes in hearing of contralateral ear, it is of great significance in patients with only one hearing ear.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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