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RESEARCH ARTICLE

How Drill-Generated Acoustic Trauma effects Hearing Functions in an Ear Surgery?

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ABSTRACT

Objective: In otology, a wide variety of devices are used that have significant noise output, both operated ear and the patient. We aimed to determine hearing damages due to drill-generated acoustic trauma in ear surgery. We want to find how degree drill-generated acoustic trauma is responsible from sensorineural hearing loss in ear surgery.

Materials and methods: We designed a retrospective study about 100 patients who underwent radical or modiphied radical mastoidectomy and tympanoplasty. The audiometric testing was done both pre and postoperatively to detect any significant hearing loss in the immediate postoperative period. The data were analyzed using the Wilcoxon sign and Mann-Whitney U tests. This study proposes that hearing loss is caused by drill noise conducted to the operated ear by vibrations of temporal bone.

Results: A sensorineural hearing loss soon after mastoid surgery is seen due to the noise generated by the drill. Mean pure-tone thresholds obtained was significantly more in mastoidectomy applied patients when compared to tympanoplasty . Mean bone conduction (BC) hearing levels impaired 6,6 dB in 1 kHz ,5.5 dB in 0.5 kHz , 5 dB in 4.kHz and 3.1 dB in 2 kHz in mastoidectomy groups but improved 5.5 dB in 0.5 kHz, 2.2 dB in 1 kHz , 2.7 dB in 2 kHz in tympanoplasty groups. Statistically significant differences were observed at the 0.5-1 and 4 kHz frequencies pre and postoperative in the hearing thresholds of BC changing in mastoidectomy group, however, the averages of ranks of all pre and postoperative measurement of hearing levels show differences between mastoidectomy and tympanoplasty groups was significant in statistically at independent groups ($p < 0.05$).

Conclusion: We conclude that drill-generated noise during mastoid surgery has been incriminated as a cause of sensorineural hearing loss. Drilling during mastoid surgery may result in temporary or permanent noise-induced hearing loss. Possible noise disturbance to the inner ear can only be avoided by minimizing the duration of harmful noise exposure and carefull using burr to near the cochlear structures.

Keywords: Noise-induced hearing loss, Mastoidectomy Hearing impairment.

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INTRODUCTION

The exposure of ear to noise is a well known factor which can lead to sensorineural hearing loss (SNHL). In otology, a wide variety of devices are used that have significant noise outputs. If a patient gets exposed to a loud noise during an ear surgery, this can result as a surgical trauma.[1] Drill and surgical tools can especially cause noise-induced hearing loss when used on or adjacent to the ossicular chain and stapes footplate and during the work on the mastoid bone, therefore the drill-generated noise has been incriminated as a cause of SNHL in the operated ear.[2] The manner in which the variables rotation speed, type of burr, burr size and site of drilling influence bone-conducted, drill-generated noise levels in ear surgery has been investigated.[3] When a drill is used during a mastoid surgery, the noise level in the cochlea is calculated from vibration measurements on intact skulls of human cadavers and temporal bones.[4] Everytime when a drill is used, the ipsilateral cochlea is exposed to noise levels of about 100 dB and the contralateral cochlea to levels of 5 to 10 dB lower.[5] For example, when drilling in the mastoid cavity, the noise levels range from 85 to 117 dB. During cochleostomy noise levels ranged from 114 to 128 dB SPL when recordings were made close to the round window.[1]

Drill-generated noise levels and the exposure time interval determines the hearing loss levels related to the surgery type. In a mastoid surgery, higher levels of noise-induced hearing losses are expected due to longer time of exposure to drilling. These risks can also continue if lasers are used. It can also produce acoustic trauma. For this reason, surgeons should carefuly consider these differences when selecting and applying these tools, especially when used on or adjacent to the ossicular chain and stapes footplate.[6] Noise generating tools must be kept away from cochlea and use within short time as possible for the reasons explained above. Drill-induced noise levels in an ear surgery cannot be reduced to any great extent. Possible noise traumas to the inner ear can only be avoided by minimizing the duration of drilling and thus, the duration of harmful noise exposure to the cochlea.[3]

Drilling in mastoid surgery may result in temporary noise-induced hearing loss. This has practical implications for both the patient and the surgeon.[7] Noise exposure results in dysfunction of the outer hair cells, which may produce a temporary hearing loss on surgery applied or other ears.[8] Tympanoplasty can also cause a SNHL by a mechanism of acoustic trauma. Although this lesion appears to be relatively infrequent in clinical practice, its low apparent incidence is caused when clinicians fail to assess the auditory frequencies above 8,000 Hz.[9]

In this study, we have aimed to determine the hearing damages in ear surgeries in radical and modified radical mastoidectomy applied ears; to determine why they required longer time drilling exposure as compared to tympanoplasty; why they required less time or no use of drill. Changes in the hearing levels were evaluated especially in the bone conduction thresholds at the pre- and postoperative period. In this study we want to find the effects of ear surgery on hearing and cochlear functions.

MATERIALS AND METHODS

A retrospective study which was set up about damages in the cochlea after the acustic or surgical trauma of middle-ear and mastoid surgery.

The basis of this study included 100 patients who had undergone tympanoplasty or mastoidectomy between July 2004 and December 2010 at Dr Lutfi Kirdar Training and Research Hospital.

Three surgical techniques were evaluated. Radical and modified radical mastoidectomy were applied with drill-generated noise, tympanoplasty was applied by only using surgical manipulations hence no drills were used. There were 39 patients in the first group where only tympanoplasty was applied without using a drill (n = 39), radical (n = 38) and modified radical (n = 23) mastoidectomy was applied to 61 patients in the second group.

Standard pure-tone audiometry (PTA) were measured for all patients before, 1 week and at least 3 months after middle ear or mastoid surgery to detect any significant hearing losses in the postoperative period. Mean pure-tone thresholds (PTA) obtained and analyzed in mastoidectomy were compared to tympanoplasty patients before and after surgery.

Bone conduction audiometric thresholds PTAs were calculated and compared pre- and postoperatively with hearing levels at 0.5, 1, 2, 4 kHz in two groups. Every changes of the bone conduction hearing levels were recorded as either increased or decreased in. Their ranges were evaluated and analyzed statistically.

We have collected all the information on possible damaging mechanisms and the degree of three surgical techniques. The comparison of the bone conduction thresholds with audiometry results was able to be done after healing of the ear is completed. We have aimed to find how the bone conduction hearing levels are effected from drill induced noise exposure in mastoid surgery.

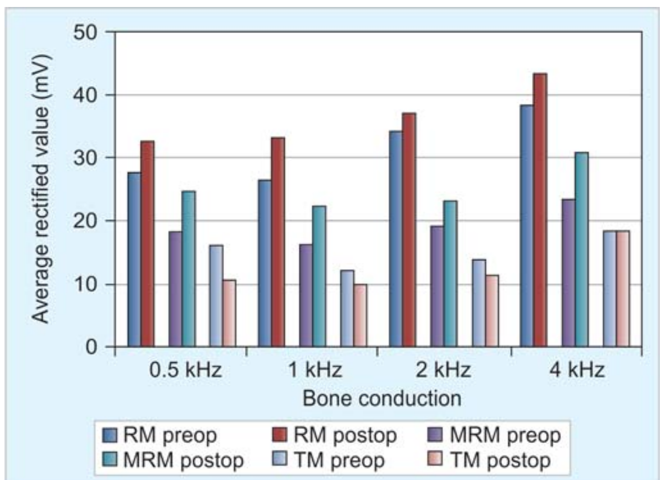
Statistical Analysis

Statistical analysis was performed by using Mann-Whitney U test. Nonparametric Mann-Whitney U analyses were used when the hearing level ranks of pre- and postoperatively measurement has differences between mastoidectomy and tympanoplasty groups or not. The comparison of rank of averages in measurement in mastoidectomy and tympanoplasty applied patients was achieved using Wilcoxon signed rank test. Statistical significance was taken of 95% confidence intervals in the estimation of results, p-values of <0.05 were considered to be statistically significant.

RESULTS

Postoperatively, 67% of patients (41/61) showed hearing impairment in mastoidectomy applied group, 31.1% (19/61) showed impairment, more than 5 dB, 22.9% of patients (14/61) showed hearing improvement, 16.4% (10/61) showed improvement more than 5 dB, 9.8% of patients (6/61) showed no change compared with preoperative level. Postoperatively, 17.9% of patients (7/39) showed hearing impairment in tympanoplasty applied group. A total of 12.8% (5/39) showed impairment more than 5 dB, 58.9% of patients (23/39) showed hearing improvement, 51.3% (20/39) showed improvement more than 5 dB, 23% of patients (9/39) hearings stayed at the same level as the preoperative levels (Graph 1).

The findings in this study indicate that drilling of the temporal bone can impair the hearing levels in all frequencies in a significant number of patients.

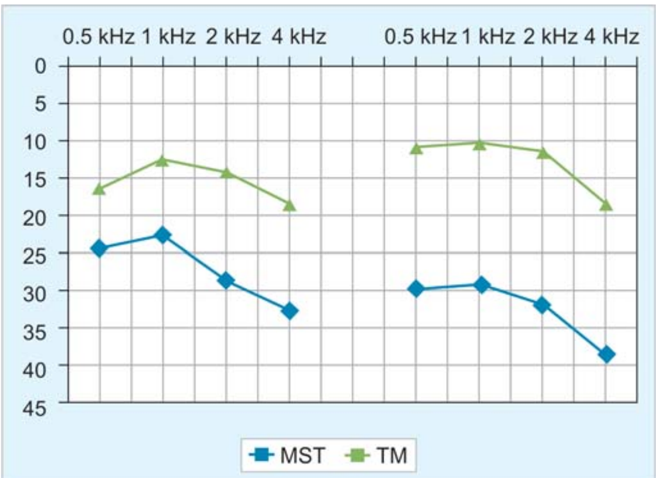


	Preoperative (dB)				Postoperative (dB)			
	0.5 kHz	*1 kHz*	*2 kHz*	*4 kHz*	*0.5 kHz*	*1 kHz*	*2 kHz*	*4 kHz*
RM	27.8	26.5	34.3	38.4	32.8	33.3	37.2	43.4
MRM	18.7	16.3	19.6	23.5	24.8	22.4	23.3	30.9
TM	16.4	12.6	14.2	18.6	10.9	10.4	11.5	18.6

Graph 1: The mean BC hearing levels of patients decreases postoperatively in modified radical and radical mastoidectomy, especially at 0.5 to 4 kHz but vice versa in hearing levels of patients with tympanoplasties increases apparently at 0.5,1,2 kHz and stay at the same level as the preoperative levels at 4 kHz

When the mean bone conduction (BC) of hearing levels of patients were evaluated, markedly change was found in hearing capacity that were impaired 6.6 dB in 1 kHz, 5.5 dB in 0.5 kHz, 5 dB in 4.0 kHz and 3.1 dB in 2 kHz in mastoidectomy applied ears.

The mean BC of hearing levels did not change in 4 kHz, although markedly change was found as improvement 5.5 dB in 0.5 kHz, 2.2 dB in 1 kHz, 2.7 dB in 2 kHz in hearing capacity in tympanoplasties (Graph 2).



	Preoperative				Postoperative			
	0.5 kHz	*1 kHz*	*2 kHz*	*4 kHz*	*0.5 kHz*	*1 kHz*	*2 kHz*	*4 kHz*
MST	24.3	22.6	28.8	32.8	29.8	29.2	31.9	38.7
TM	16.4	12.6	14.2	18.6	10.9	10.4	11.5	18.6

Graph 2: Pre- and postoperative mean BC hearing levels in mastoidectomy (MST) and tympanoplasty (TM) applied patients

It was found that cochlear damage could occur due to surgical and acustic trauma in mastoidectomy-applied ears. Especially 1 kHz frequency was mostly effected but other frequencies also effected; 0.5, 4 and 2 kHz respectively (Graph 3).

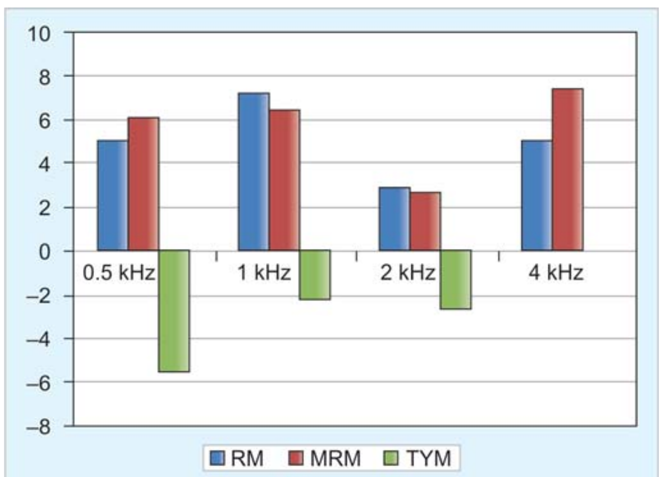
Statistically significant differences were observed at all frequencies (0.5-4 kHz), at bone conduction theresholds in mastoidectomy-applied patients before and after surgery when analyzed with Wilcoxon signed and Mann-Whitney U test ($p < 0.05$; Tables 1 to 3).

Mean pure-tone bone conduction thresholds were significantly more impaired in mastiod surgery patients when compared to tympanoplasty patients.

DISCUSSION

When any surgical procedure is to be applied to an organ, any levels and end points of function changes must be known. Ear surgery and surgical tools must monitorize well on benefits and risks prior to the surgery. The operated ear is exposed to some degree of acoustic and surgical trauma. In this study, we have tried to determine the levels of acoustic trauma or drill-generated noise damages on hearing functions.

Use of drills in ear surgeries can generate noise levels causing an acoustic trauma.



	Preoperative (dB)					Postoperative (dB)			
	0.5 kHz	*1 kHz*	*2 kHz*	*4 kHz*		*0.5 kHz*	*1 kHz*	*2 kHz*	*4 kHz*
MAST(dB)	5.5	6.6	3.1	5	RM (dB)	5	7.2	2.9	5
TYM (dB)	– 5.5	– 2.2	– 2.7	0	MRM (dB)	6.1	6.5	2.7	7.4
					TYM (dB)	– 5.5	– 2.2	– 2.7	0

Graph 3: Mean bone conduction hearing levels changes after surgeries (dB) (negative values show improvement, positive values show impairment of BC thresholds). MAST: Mean bone conduction hearing levels changes in mastoidectomy-applied patients; TYM: Mean bone conduction hearing levels change in tympanoplasty-applied patients; RM: Radical mastoidectomy; MRM: Modified radical mastoidectomy

Some studies have found that noise levels were 84 to 128 dB. This effect shows that either temporary threshold has shifted or that persistant hearing loss has occured.[1,6] Possible procedures that can cause acoustic trauma are a stapes surgery with the opening of the inner ear, mastoidectomy with drill-generated noise and tympanoplasty with manipulations at the stapes or other ossicle.

In a study normal BC audiometric thresholds scheduled for tympanoplasty were assessed with an electrostimulation, BC high-frequency audiometer which can measure hearing frequencies up to 20 kHz before and after surgery. A measurable hearing loss was found in the upper limits of the audible frequencies in 37.5% and was considered important in 16.7%. This hearing loss was recorded above the upper frequency limit of conventional audiometers. The drilling of the temporal bone can impair the hearing level in the high frequencies seen in a significant number of patients.[9] In our study, 67% mastoidectomy applied patients showed hearing impairement, 47.5% of them showed 5 dB above loosing their mean hearing BC levels.

Another authors have described that the noise trauma may account some patients in high-tone frequencies after tympanoplasty.[5] It is suggested that the high-frequency audiometry is a very sensitive tool to assess any damage to inner ear due to surgical procedures on the middle ear and temporal bone.[9]

The comparison of the bone conduction thresholds with audiometry results after completed healing of the ear is completed, disclosed that even under packed ear, BC can give reliable information on cochlea function, if 10 to

Table 1: The comparison of rank of averages in measurement in mastoidectomy-applied patients [(Wilcoxon signed test) n = 61]

Hearing fr (BC)	*Mean (BC)*	*Standard deviation*	*Z*	*p*
Preop 0.5 kHz	24.34	17.87	–3.005	0.003
Postop 0.5 kHz	29.75	17.85		
Preop 1 kHz	22.62	19.03	–3.238	0.001
Postop 1 kHz	29.18	21.48		
Preop 2 kHz	28.77	20.40	–1.882	0.060
Postop 2 kHz	31.96	23.20		
Preop 4 kHz	32.78	21.12	–3.004	0.003
Postop 4 kHz	38.68	25.80		

Statistically significant differences were observed at 0.5, 1 and 4 kHz frequencies with Wilcoxon signed test in repeated measurement of mean bone conduction thresholds in radical mastoidectomy-applied patients before and after surgery ($p < 0.05$)

Table 2: The comparison of rank of averages in measurement in timpanoplasty-applied patients [(Wilcoxon signed test) n = 39]

Hearing fr (BC)	*Mean (BC)*	*Standard deviation*	*Z*	*p*
Preop 0.5 kHz	16.41	7.77	–3.265	0.001
Postop 0.5 kHz	10.89	8.87		
Preop 1 kHz	12.56	9.09	–1.815	0.070
Postop 1 kHz	10.38	10.59		
Preop 2 kHz	14.23	9.42	–1.709	0.088
Postop 2 kHz	11.53	12.46		
Preop 4 kHz	18.58	16.42	–0.180	0.857
Postop 4 kHz	18.58	17.31		

Statistically significant differences were observed in repeated measurement of mean bone conduction thresholds in radical mastoidectomy-applied patients before and after surgery with Wilcoxon signed test ($p < 0.05$)

Table 3: Nonparametric Mann-Whitney U analyses table [the analyses table is shown in which the hearing level ranks of pre- and postoperative measurement is getting differences between mastoidectomy (group = 1) and tympanoplasty (group = 2) groups or not)]

	Group	*n*	*Mean rank*	*Sum of ranks*	*U*	*Z*	*p*
Rank 0.5 kHz	1	61	40.33	2,460.00	569.000	–4.421	0.000
	2	39	66.41	2,590.00			
Rank 1 kHz	1	61	42.17	2,572.50	681.500	–3.634	0.000
	2	39	63.53	2,477.50			
Rank 2 kHz	1	61	43.75	2,668.50	777.500	–2.951	0.003
	2	39	61.06	2,381.50			
Rank 4 kHz	1	61	45.25	2,760.00	869.000	–2.283	0.022
	2	39	58.72	2,290.00			

Applied Mann-Whitney U test results showed that the averages of ranks of all pre- and postoperative measurement of hearing levels was getting differences between mastoidectomy (group = 1) and tympanoplasty (group = 2) groups which was significant in statistically at independent groups ($p < 0.05$)

15 dB variance due to methodological causes is taken into account. Excessive drilling may result in a temporary threshold shift, which can readily be resolved at the time of unpacking the ear. After manipulation at the stapes, no signs of hydraulic damage could be discovered.[10]

Some studies could not find any adverse effects of the noise generated by the drill on the hearing function. The audiograms from 50 consecutive patients with acoustic neuromas undergoing the translabyrinthine approach were compared before and 3 months after surgery. Postoperatively no cases of sensorineural hearing impairment could be demonstrated.[11]

It is suggested that there is no damage in the contralateral ear exclusively due to the drill noise during the mastoid surgery. The contralateral ear has been subjected to the drill noise, but it has been spared from the surgical trauma. Sound pressure levels did not exceed 84 dB in the operated ear and 82 dB in the contralateral ear.

Although some SNHL was found in the operated ear in 6.5% of the patients, there were no changes in hearing in the contralateral ear.[2] In our study, 31.1% of the patients showed hearing impairment of 5 dB above in mastoidectomy applied group.

Burr types and sizes can affect the acoustic trauma levels. In a study, three different types of cutting burrs has been tested. The 6 mm cutting burrs had given a noise level of 88 to 108 dB, the use of a 4 mm one resulted in a reduction of 1 to 6 dB and the use of a 2 mm one, 5 to 16 dB. The mean noise levels of the diamond burrs had been 5 to 11 dB lower than the mean noise levels of the cutting burrs. Variations in rotation speed had only a slight influence on the noise levels produced (0-5 dB).[3] It was suggested that all drills emitted noise exceeding 85 dB. The pneumatic drill reached noise levels of up to 114 dB, while the shielded self-propelled drill almost complied with the 85 dB 8 hours exposure limit. Isolating the operator from the drill, as for the self-propelled drill, addresses the problems of both vibration and noise exposure, and is a possible direction for future development.[12] Reversible drill-related outer hair cell dysfunction was seen in 16.7% of the operated ear cases.[8] The organ of Corti could be examined in its entirety with a scanning electron microscope. It was found that the drill with the lowest rpm (and highest torque) produced the highest noise intensities, which can reach levels that can be traumatic to the ears. The high and very high speed drill inflicted less damage on the organ of Corti than the low speed drill. Therefore, it is advised to refrain from using low speed drills in prolonged operations.[13]

The drilling device should so be designed so as to avoid acoustic trauma. The sound level for drilling in the mastoid exceeded 100 dBA . Furthermore, a surgical technique should be selected, which minimizes the noise levels and duration of exposure as short as possible.[14] We have used all types of burrs in all mastoidectomy operations. We need various size of burrs for working in special areas. We have observed some degree of hearing impairment in mean BC of hearing levels of patients. The markedly change found in hearing capacity of ears were 6.6 dB in 1 kHz, 5.5dB in 0.5 kHz, 5 dB in 4.0 kHz and 3.1 dB in 2 kHz worsening in mastoidectomy applied ears.

In order to lower the acoustic taruma in an ear surgery, size and type of burr must be known preoperatively. We have determined the effect levels of ear surgery and drill-generated acoustic trauma on cochlear function demanding to operative data. The comparison of the bone conduction thresholds with audiometry results, after healing of the ear is completed, was performed to both tympanoplasty and/or mastoidectomy. We have obtained statistically significant differences between mastoidectomy-applied ear compared to tympanoplasty-applied ear. The changes in the hearing function and drill-generated noise-induced acoustic trauma are discussed.

There is no study based on the comparison of the bone conduction thresholds with audiometry results after healing of the ear is completed in two different methods as tympanoplasty without using a drill and mastiodectomy by using excessive drill procedures.

CONCLUSION

This study data indicates that noise levels of drilling during mastoid surgery can impair the hearing level as 6.6 dB in 1 kHz, 5.5 dB in 0.5 kHz, 5 dB in 4.0 kHz, 3.1 dB in 2 kHz frequencies in a significant number of patients.

Drill-generated noise cannot be reduced to any great extent. But it has been incriminated as a cause of about 5 dB SNHL in all frequencies in mastoidectomy-applied ears. If a mastoidectomy is to be applied by using a burr in any ear, it must be well known that the hearing capacity can decrease between 3.1 and 6.6 dB.

The drill-induced noise to be one of the cause of hearing loss must be thought during mastiod surgery. Possible noise disturbance to the inner ear can only be avoided by minimizing the use of burr because of harmful noise exposure to the cochlear structures.

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