Noise & Health
A Bimonthly Inter-disciplinary International Journal
Home
Current issue
Instructions
Submit article

Noise Health. 2015 Jul-Aug; 17(77): 209–215. PMCID: PMC4900484
doi: 10.4103/1463-1741.160691

The effect of drill-generated noise in the contralateral healthy ear following mastoid surgery: The emphasis on hearing threshold recovery time

Mohammad Hossein Baradaranfar, Honeyeh Shahbazian, Nasim Behniafard, Saeid Atighechi, Mohammad Hossein Dadgarnia, Abbas Mirvakili, Abolfazl Mollasadeghi, and Amin Baradaranfar

Otolaryngology Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

Address for correspondence: *Dr. Honeyeh Shahbazian, Department of Otolaryngology, Head and Neck Surgery, Otorhinolaryngology Research Center, Shahid Sadoughi Hospital, Avicenna Blv., Safayeh, Yazd, Iran. E-mail: shahbazian.honeyeh@gmail.com*

Abstract

In mastoid surgeries, contralateral ear noise exposure is a known, identified factor leading to high-frequency hearing loss due to the wide variety of surgical devices that may be used during the surgery. However, the hearing threshold recovery time after this trauma was uncertain. The present study aimed to assess this time. In this prospective survival analysis study, 28 consecutive patients with chronic otitis media who were undergoing tympanomastoidectomy were assessed. Standard pure-tone audiometry (PTA) and distortion-product otoacoustic emission (DPOAE) were measured in all contralateral ears before and 6 h, 24 h, 48 h, 72 h, and 96 h after the surgery. Based on the PTA postoperative hearing loss, survival rates at frequencies of 3000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz were 44.4%, 36.4%, 51.7%, and 47.4%, 24 h after surgery; 11.1%, 9.1%, 10.3%, and 13.2%, 48 h after surgery; and 0%, 0%, 3.4%, and 2.6%, 72 h after surgery, respectively. Based on the PTA and DPOAE, survival rates at all frequencies were 0%, 96 h after the surgery. According to the PTA, mean hearing recovery times were 61.98 ± 26.76 h (3000 Hz), 62.73 ± 26.50 h (4000 Hz), 67.08 ± 25.90 h (6000 Hz), 70.70 ± 24.13 h (8000 Hz), and with regard to DPOAE the recovery times were 58.58 ± 28.39 h (2000 Hz), 63.32 ± 28.83 h (4000 Hz), 65.22 ± 29.13 h (6000 Hz), and 75.14 ± 22.70 h (8000 Hz), respectively. To conclude, high-frequency hearing loss usually occurs following mastoid surgeries that is mainly temporary and reversible after 72 h.

Keywords: *Chronic otitis media*, *hearing loss*, *mastoid*, *noise*, *survival*

Introduction

The exposure of the ear to noise is a known, identified factor leading to hearing loss.[1,2,3] In various types of surgeries of the ear and ear-related conductive bones, a wide variety of devices are used that are potential sources of high-frequency noise outputs, which accounts for cochlear acoustic trauma.[4,5,6] Drills and surgical tools (such as suctions) can especially cause noise-induced hearing loss when used on or adjacent to the ossicular chain and stapes footplate and during work on the mastoid bone, thus drill-generated noise has been ascertained as the main cause of hearing loss in the operated ear and even in the contralateral healthy ear.[7,8,9,10] By drill administration during mastoid surgery, the healthy ear may be exposed to severe noise levels.[11] It has been shown that drilling in mastoidectomy may involve exposing the ear to noise of about 100 dB and the contralateral cochlea to levels 5-10 dB lower.[12,13] In this context, drill-generated noise levels and the exposure time interval may be major determinants of hearing loss levels.[14] In a mastoid surgery procedure, higher levels of noise-induced hearing losses are expected due to longer times of exposure to drilling.[6] In most patients, drilling in mastoid surgery may result in temporary noise-

induced hearing loss, especially in the contralateral healthy ear;[7,15,16] however, the hearing threshold recovery time in the contralateral healthy ear after acoustic trauma and its main determinants remain uncertain. The present study aimed to assess hearing threshold recovery in the contralateral healthy ear after acoustic trauma following mastoid surgery.

Methods

From June 2012 to June 2014, 28 consecutive patients (13 male, 15 female) with chronic otitis media or even cholesteatoma who had been scheduled for tympanomastoidectomy of either the “canal wall down” type or the “canal intact” type, which would be decided at the operational time based on the severity of the disease, were included in this prospective survival analysis study. The patients had been selected consecutively from two hospital clinics of Shahid Sadoughi University of Medical Sciences (Shahid Sadoughi and Shahid rahnemoon hospital clinics), but the site where the audiologist did the primary and postoperative acoustic evaluation and the hospital where each patient was operated on were the same (Shahid Sadoughi Hospital).

All patients had normal contralateral ear. The main exclusion criteria for this study were as follows: An underlying ear disorder in the healthy ear; lack of regular follow-up of patients; unwillingness to participate in the study; the presence of at least 4 days in the hospital; a history of the recent usage of ototoxic medications or any type of previous otologic surgeries on each side; or a history of Ménière's disease or any kind of systemic disease, including even psychological disorders. Baseline data such as gender and age were collected by interviewing. In addition, the type of surgery, side of the involved ear, and mean time of drilling were also noted by reviewing the records files of the operating room. This study was the result of a residency thesis at Shahid Sadoughi Hospital of Shahid Sadoughi University of Medical Sciences and was approved by the Ethics Committee of Research and the Vice-Chancellor of the University. Written consent forms were assigned by our patients for their informed participation in the present study (in Persian). The target ear (the healthy one) was normal in each patient in all otoscopic, microscopic, and audiometric presurgical examinations.

Audiological assessment tools

Pure-tone audiometry (PTA) Standard PTA (AC40, Interacoustic, Assens, Denmark, headphone: TDH39) was performed before the tympanomastoidectomy and 24 h, 48 h, 72 h, and 96 h after the surgery. Pure-tone air and bone conduction audiometries for the frequencies of 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, and 8000 HZ were measured for all targeted contralateral healthy ears. These measurements were continued until threshold hearing levels returned to their presurgical statuses.

Distortion-product otoacoustic emission (DPOAE) DPOAE values were measured using Madsen's Capella equipment (GN Otometrics Ltd., Taastrup, Denmark) by the same constant audiologist for all patients before surgery as well as 6 h after surgery and continued every 24 h to detect any significant hearing losses in the postoperative period until hearing thresholds reached their baseline measures. The data were evaluated by an optoacoustic emission (OAE) software (Otoscreen OAE screening and Noah-based software, Assens, Denmark). DPOAE was calculated and compared pre- and postoperatively with hearing levels at 0.5 kHz, 1 kHz, 2 kHz, 4 kHz, 6 kHz, and 8 kHz. Every change in hearing level was recorded as either increased or decreased. The f2/f1 ratio was held at 1/2. The stimuli levels were pointed constant levels at L1 = 65 dB SPL (sound pressure level) and L2 = 55 dB SPL. The amplitude levels were also calculated. Their ranges were evaluated and analyzed statistically. Also, the hearing threshold recovery time at each frequency was recorded. All patients received similar medications for general anesthesia and after the procedure. Additionally, all procedures were conducted using a similar type of drill with a drill speed of about 1700 rounds/min, and by the same surgeon (the first author). At the end of the study, all participants were also asked to state their feelings regarding hearing loss or hearing improvement at different time points after surgery.

The results were reported as mean ± standard deviation (SD) for the quantitative variables and percentages for the categorical variables. The groups were compared using Student's *t*-test or the Mann-Whitney *U* test for the continuous variables and the chi-square test (or Fisher's exact test, if required) for the categorical

variables. Changes in quantitative parameters after the exercise test compared with before the test were detected by a paired *t*-test or the Wilcoxon signed-rank test. Kaplan-Meier survival analysis was used to determine the overall survival of hearing loss. P values of 0.05 or less were considered statistically significant. All the statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA).

Results

In this study, 28 patients were assessed with the mean age 35.57 ± 11.61 years (median 32.5 years, range 16 to 62 years); of them, 46.4% were male. The healthy ear was on the right side in 39.3% and on the left side in 60.7% of patients. There was no significant statistical difference in hearing recovery time between different frequencies according to patients' gender or the side of the affected ear. The mean time of drilling was 56.48 ± 12.70 min (median 55 min, range 40-90 min) which was not statistically relevant to the hearing recovery time period. Regarding the level of hearing based on PTA, there was a significant difference in hearing level 24 h after surgery compared to that before surgery at frequencies of 3000-8000 Hz. Mean hearing threshold changes, considering all frequencies, were 4.2 dB after 24 h, 4.26 dB after 48 h (without any statistical significance at 3 kHz and 4 kHz), and 9. 4 dB, after 72 h of the surgery (which was only statistically considerable at 6 kHz and 8 kHz). Mean hearing loss in regarding each of the examined frequencies has been described in dB in Table 1 in detail.

There was no significant change in hearing levels at 250 Hz, 500 Hz, and 1000 Hz based on the PTA or DPOAE [Figures 1–5]. Also, the difference in the level of hearing based on PTA was shown in two cases 96 h after surgery at two frequencies of 6000 Hz and 8000 Hz, which was not statistically significant. Furthermore, according to DPOAE analysis, the difference in the level of hearing was found 6 h and 24 h after surgery at frequencies of 2000-8000 Hz. The difference in hearing levels at 48 h and 72 h after surgery compared to before surgery was significant at the frequencies of 4000 Hz, 6000 Hz, and 8000 Hz. However, this difference was found in none of frequencies at 96 h after surgery when compared to before surgery. At the beginning of the study, if a patient forgot to smention any particular drug that he used to take for any other medical disorder, such as acne vulgaris (isotretinoin), because in his opinion, that drug was not related to the ear problem, we were forced to omit him from the study because that very drug has been proved to have significant effects on PTA hearing levels.[17] Thus, after that we tried to ask about each type of drug that has documented side effects on the outer hair cells of the cochlea from each case orally, and documented the findings in the preliminary presurgical interview and visits.

With respect to the survival of hearing loss based on PTA, the survival rate in nonoperated ears at frequencies of 3000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz was 44.4%, 36.4%, 51.7%, and 47.4%, 24 h after surgery; 11.1%, 9.1%, 10.3%, and 13.2%, 48 h after surgery; and 0%, 0%, 3.4%, and 2.6%, 72 h after surgery. At all frequencies at 96 h after surgery, the survival rate of hearing loss was determined to be 0%. In this regard, the survival rate in the nonoperated ear based on DPOAE at frequencies of 2000 Hz, 4000 Hz, 6000 Hz, and 8000 Hz was 96.4%, 94.3%, 94.3%, and 99.3%, 6 h after surgery; 74.9%, 86.7%, 89.2%, and 97.5%, 24 h after surgery; 49.9%, 64.0%, 70.1%, and 82.4%, 48 h after surgery; and 25.0%, 33.1%, 38.8%, and 54.5%, 72 h after surgery, respectively. Tables 2 and 3 depict these survival percentages as the number of each patients with constant hearing loss, according to the postsurgical time at each frequency. At all frequencies at 96 h after surgery, the survival rate of hearing loss was 0%. The mean hearing recovery time for nonoperated ears based on PTA was 61.98 ± 26.76 h (at 3000 Hz) [Figure 6], 62.73 ± 26.50 h (4000 Hz) [Figure 7], 67.08 ± 25.90 h (6000 Hz) [Figure 8], and 70.70 ± 24.13 h (8000 Hz) [Figure 9]. Also, the mean hearing recovery time for nonoperated ears based on DPOAE was 58.58 ± 28.39 h (2000 Hz) [Figure 10], 63.32 ± 28.83h (4000 Hz) [Figure 11], 65.22 ± 29.13 h (6000 Hz) [Figure 12], and 75.14 ± 22.70 h (8000 Hz) [Figure 13].

Mean hearing thresholds (expressed as dB) at different frequencies based on PTA and hearing loss amplitudes (SPL) of patients according to the frequencies in DPOAE are shown in Tables 1 and 4 respectively.

Mean hearing loss levels [pre-and postoperation difference (in dB)] of patients according to the frequencies in PTA have been illustrated in Table 5.

With regard to the patients' feelings regarding changes in hearing level, the similarity in hearing levels before and after surgery at 24 h, 48 h, 72 h, and 96 h after surgery was reported in 17.9%, 35.7%, 46.4, and 96.4% of cases respectively.

Discussion

The present study attempted to assess hearing loss survival originating from drilling in the healthy, nonoperated ear in patients who were undergoing mastoid surgery. In fact, we aimed to determine the time point for achieving complete healing and recovery of hearing in the healthy ear after drilling of the mastoid. The main point of the study was that the hearing recovery time in the nonoperated ear was mostly less than 72 h with, on average, 65.56 ± 27.26 h and 65.62 ± 25.8 h for PTA and DPOAE respectively. On the other hand, the survival of hearing loss in this ear lasted for less than 72 h. In fact, following the drilling in the mastoidectomy procedure, hearing loss especially at the frequencies higher than 2000 Hz may occur that is mainly temporary and reversible, leading to complete recovery after 72 h. A few studies assessed the mean recovery time for recovered hearing levels. In the Migirov and *et al*. study,[18] the DPOAE amplitudes were significantly decreased at 2 kHz and 4 kHz immediately after the mastoidectomy, and still differed from the preoperative results at these frequencies on the first postmastoidectomy day. After the various individual fluctuations, the DPOAE amplitudes remained decreased in some of the patients at the end of the study. In the Karatas *et al*. study,[19] the amplitudes of the OAEs of contralateral normal ears were found to be affected immediately after surgery, and progressive improvement was detected with full recovery in 72-96 h. None of the patients showed permanent deterioration in OAE amplitudes. The burs used during mastoid surgery can cause temporary hearing threshold changes in the contralateral ears. The ear recovers from this adverse effect spontaneously within 72-96 h, postoperatively. In another study by Doménech *et al*.,[8] a measurable hearing loss was found in the upper limits of the audible frequencies in 9 patients (37.5%) and it was considered important in 4 of them (16.7%). This hearing loss was recorded above the upper frequency limit of conventional audiometers. On the contrary, in Man and Winerman's survey,[3] no changes in hearing were found in the contralateral ear, and it was thus suggested that there may be no damage exclusively due to drill noise during mastoid surgery. Also, Urquhart[10] showed that sensorineural hearing loss soon after mastoid surgery was not due to the noise generated by the drill and concluded that in the event of any hearing loss during this period, other causes should be sought. It seems that besides noise generated by drilling, other underlying factors may affect the normal hearing threshold, but according to recent reports, demographic characteristics, type of surgery, and even the parameters of drills may not have any effect. In this study, by considering normal hearing thresholds, we considered the range of thresholds within the spectrum of less than 15 dB for children and up to 25 dB for adults. These ranges include different variations of hearing sensitivities among the normal population.[20]

Despite its potential strengths, our study had some limitations. First, because of including a small sample size, the assessment of survival of hearing loss in nonoperated ears could not be assessed in different subgroups, such as of patient demographics, types of surgeries, and also duration of drilling. Second, because of the probable effects of drill characteristics on hearing loss, roles of these characteristics, such as the drill's diameter and type, need to be assessed in further studies. With regard to patients' feelings about changes in their hearing levels, there was a similarity in hearing level before and after surgery at 24 h, 48 h, 72 h, and 96 h after surgery. Statistically it has been demonstrated that what people feel about their hearing level has a significant relationship with their DOPAE hearing levels but not their PTA results. This issue is comparable with the results of previous studies, which imply that DPOAE is a more sensitive technique for the early diagnosis of outer hair cell functional impairments in the context of noise-induced hearing loss.[21,22]

Conclusion

In conclusion, the recovery time of hearing and thus the survival of hearing loss in the nonoperated ear is usually less than 72 h. Following drilling in mastoidectomy, hearing loss, especially at frequencies higher than 2000 Hz, may occur that is mainly temporary and reversible, leading to complete recovery after 72 h. The clinical impact of drill-induced hearing loss varies. Some patients with a small amount of hearing changes are completely asymptomatic, while others complain of tangible effects. Explaining this recovery

time to patients helps alleviate the anxiety after mastoidectomy procedures.

Footnotes

Source of Support: No financial support to declare

Conflicts of Interest: None to declare.

References

1. Kylén P, Stjernvall JE, Arlinger S. Variables affecting the drill-generated noise levels in ear surgery. Acta Otolaryngol. 1977;84:252–9. [PubMed: 906818]

2. Strömberg AK, Yin X, Olofsson A, Duan M. Evaluation of the usefulness of a silicone tube connected to a microphone in monitoring noise levels induced by drilling during mastoidectomy and cochleostomy. Acta Otolaryngol. 2010;130:1163–8. [PubMed: 20446822]

3. Man A, Winerman I. Does drill noise during mastoid surgery affect the contralateral ear? Am J Otol. 1985;6:334–5. [PubMed: 4025532]

4. Farzanegan G, Ghasemi M, Panahi F, Raza M, Alghasi M. Does drill-induced noise have an impact on sensorineural hearing during craniotomy procedure? Br J Neurosurg. 2010;24:40–5. [PubMed: 20158351]

5. Kylén P, Arlinger S. Drill-generated noise levels in ear surgery. Acta Otolaryngol. 1976;82:402–9. [PubMed: 998209]

6. Michaelides EM, Kartush JM. Implications of sound levels generated by otologic devices. Otolaryngol Head Neck Surg. 2001;125:361–3. [PubMed: 11593172]

7. da Cruz MJ, Fagan P, Atlas M, McNeill C. Drill-induced hearing loss in the nonoperated ear. Otolaryngol Head Neck Surg. 1997;117:555–8. [PubMed: 9374183]

8. Doménech J, Carulla M, Traserra J. Sensorineural high-frequency hearing loss after drill-generated acoustic trauma in tympanoplasty. Arch Otorhinolaryngol. 1989;246:280–2. [PubMed: 2590036]

9. Huttenbrink KB. Cochlear damage caused by middle ear surgeries. Laryngorhinootologie. 1991;70:66–71. [PubMed: 2029305]

10. Urquhart AC, McIntosh WA, Bodenstein NP. Drill-generated sensorineural hearing loss following mastoid surgery. Laryngoscope. 1992;102:689–92. [PubMed: 1602918]

11. Tos M, Trojaborg N, Thomsen J. The contralateral ear after translabyrinthine removal of acoustic neuromas: Is there a drill-noise generated hearing loss? J Laryngol Otol. 1989;103:845–9. [PubMed: 2584874]

12. Soudijn ER, Bleeker JD, Hoeksema PE, Molenaar I, van Rooyen JP, Ritsma RJ. Scanning electron microscopic study of the organ of Corti in normal and sound-damaged guinea pigs. Ann Otol Rhinol Laryngol. 1976;85(Suppl 29):1–58. [PubMed: 962272]

13. Phillips JI, Heyns PS, Nelson G. Rock drills used in South African mines: A comparative study of noise and vibration levels. Ann Occup Hyg. 2007;51:305–10. [PubMed: 17229762]

14. Holmquist J, Oleander R, Hallén O. Peroperative drill-generated noise levels in ear surgery. Acta Otolaryngol. 1979;87:458–60. [PubMed: 463518]

15. Schuknecht HF, Tonndorf J. Acoustic trauma of the coch ea from ear surgery. Laryngoscope. 1960;70:479–505. [PubMed: 14443732]

16. Lustig LR, Jackler RK, Chen DA. Contralateral hearing loss after neurotologic surgery. Otolaryngol Head Neck Surg. 1995;113:276–82. [PubMed: 7675490]

17. Ugur KS, Erpolat S, Kurtaran H, Ark N, Sarifakioglu E, Gunduz M. The effects of oral isotretinoin (13-Cis retinoic acid) on the inner ear: A clinical study. Int Adv Otol. 2005;8:339–44.

18. Migirov L, Wolf M. Influence of drilling on the distortion product otoacoustic emissions in the non-operated ear. ORL J Otorhinolaryngol Relat Spec. 2009;71:153–6. [PubMed: 19451738]

19. Karatas E, Miman MC, Ozturan O, Erdem T, Kalcioglu MT. Contralateral normal ear after mastoid surgery: Evaluation by otoacoustic emissions (mastoid drilling and hearing loss) ORL J Otorhinolaryngol Relat Spec. 2007;69:18–24. [PubMed: 17085948]

20. Roeser RJ, Clark JL. Pure tone tests. In: Brandenburg B, editor. Audiology Diagnosis. 2nd ed. New York: Thieme Medical Publishers Inc; 2007. pp. 252–3.

21. Mehrparvar AH, Mirmohammadi SJ, Davari MH, Mostaghaci M, Mollasadeghi A, Bahaloo M, et al. Conventional audiometry, extended high-frequency audiometry, and DPOAE for early diagnosis of NIHL. Iran Red Crescent Med J. 2014;16:e9628. [PMCID: PMC3964437] [PubMed: 24719719]

22. Baradarnfar MH, Karamifar K, Mehrparvar AH, Mollasadeghi A, Gharavi M, Karimi G, et al. Amplitude changes in otoacoustic emissions after exposure to industrial noise. Noise Health. 2012;14:28–31. [PubMed: 22387710]

Figures and Tables

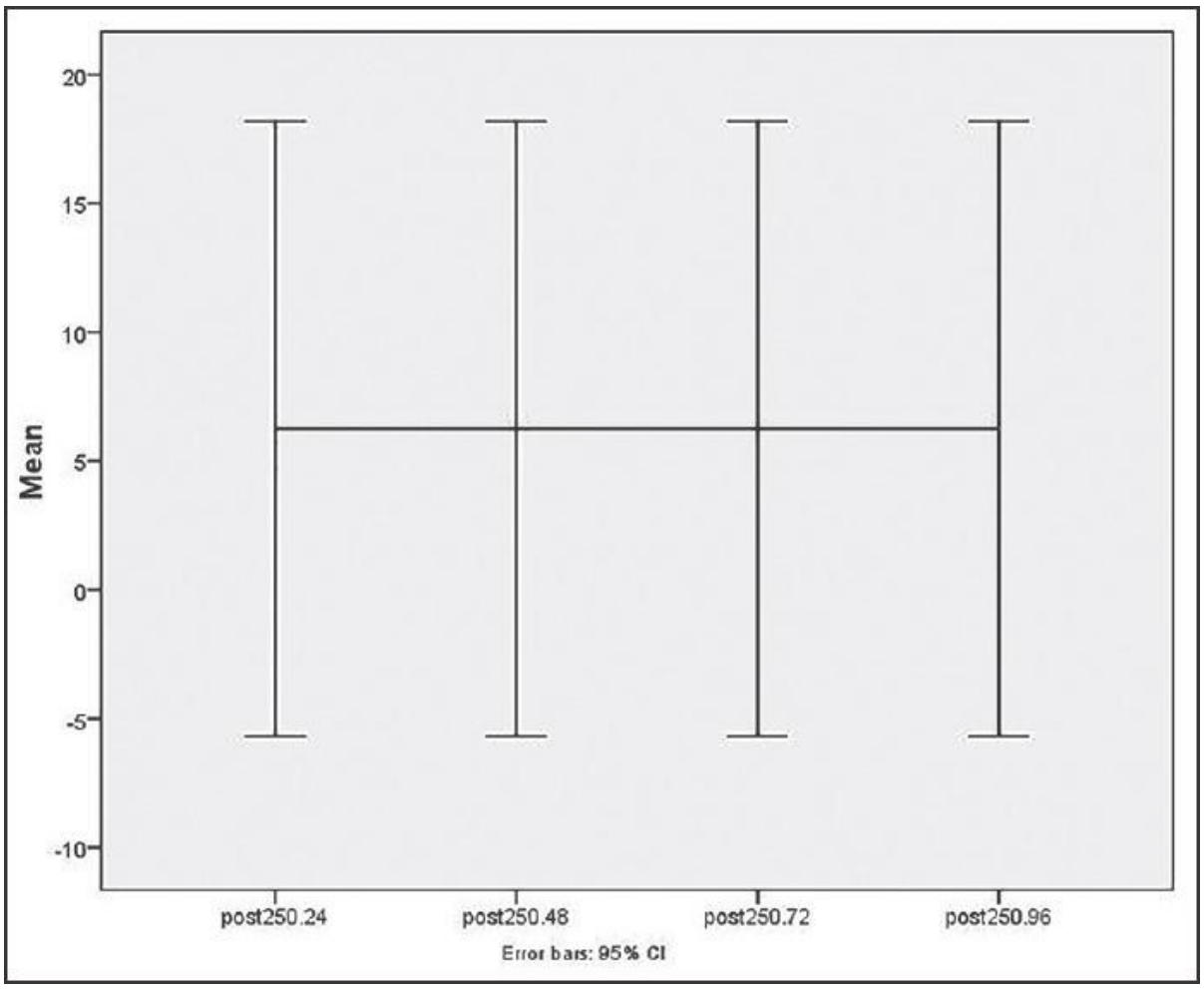
Table 1

Mean hearing thresholds (dB) at different frequencies based on the PTA

Frequency	After 24 h postop	After 48 h	After 72 h	After 96 h
250 Hz preop	5.71 dB	5.71 dB	5 dB	7 dB
250 Hz postop	5.71 dB	5.71 dB	5 dB	7 dB
500 Hz preop	6.25 dB	6.25dB	4.33 dB	6 dB
500 Hz postop	6.25 dB	6.25 dB	4.33 dB	6 dB
1 kHz preop	6.25 dB	6.25 dB	4.36 dB	7 dB
1 kHz postop	6.25 dB	6.25 dB	4.36 dB	7 dB
2 kHz preop	6.61 dB	6.61 dB	4.8 dB	6 dB
2 kHz postop	7.32 dB	6.8 dB	7 dB	6 dB
3 kHz preop	8 dB	7.68 dB	6.5 dB	7 dB
3 kHz preop	10.7 dB	9.11 dB	7 dB	7.47 dB
4 kHz preop	9.29 dB	9.64 dB	8 dB	6 dB
4 kHz preop	12.32 dB	11.25 dB	9.33 dB	9.33 dB
6 kHz preop	9.73 dB	10.45 dB	9.17 dB	8 dB
6 kHz postop	17.5 dB	16.4 dB	11.83 dB	8 dB
8 kHz preop	10.27 dB	10.98 dB	8.17 dB	8 dB
8 kHz postop	21.5 dB	16.25 dB	12.83 dB	8 dB

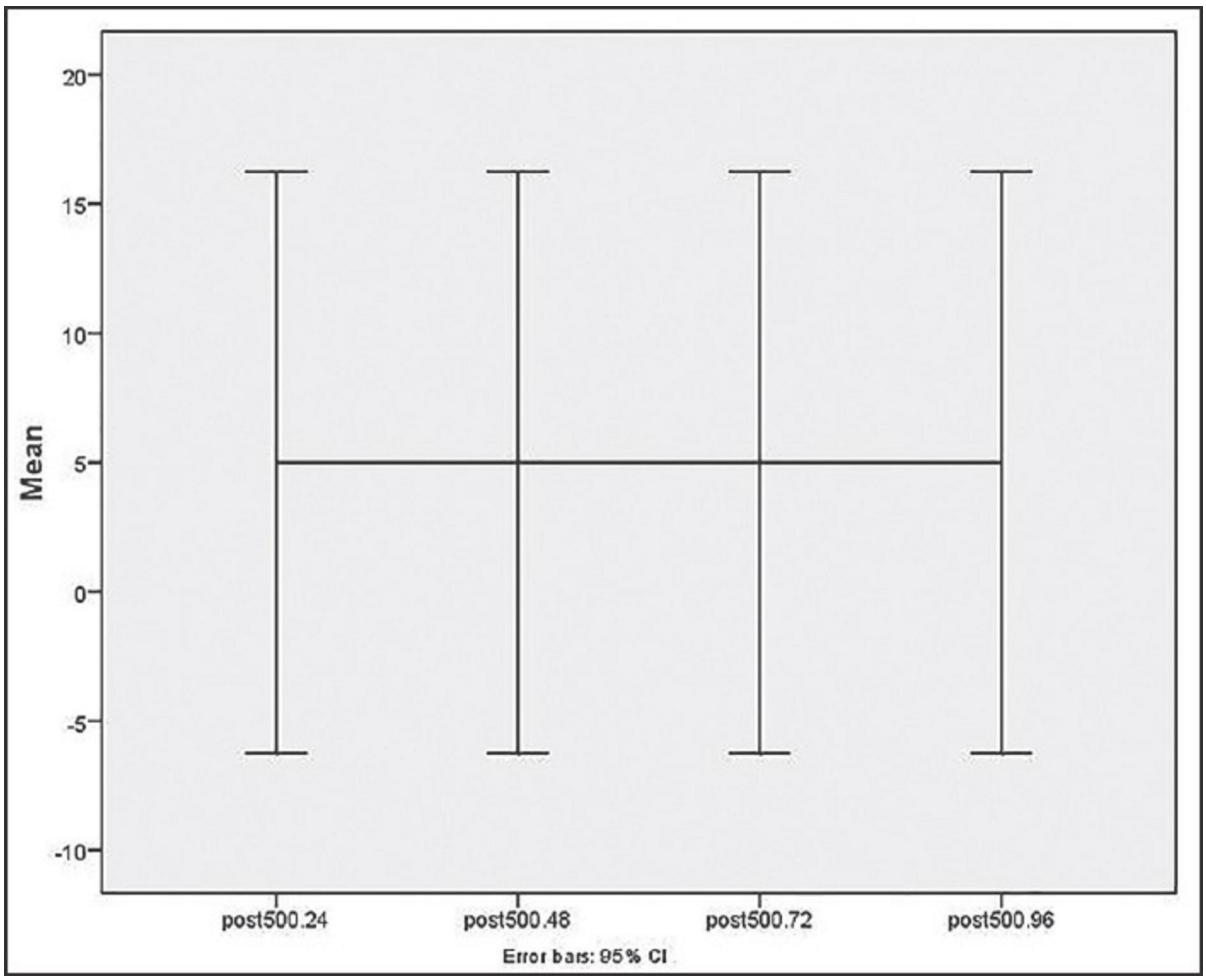
PTA = Pure-tone audiometry

Figure 1



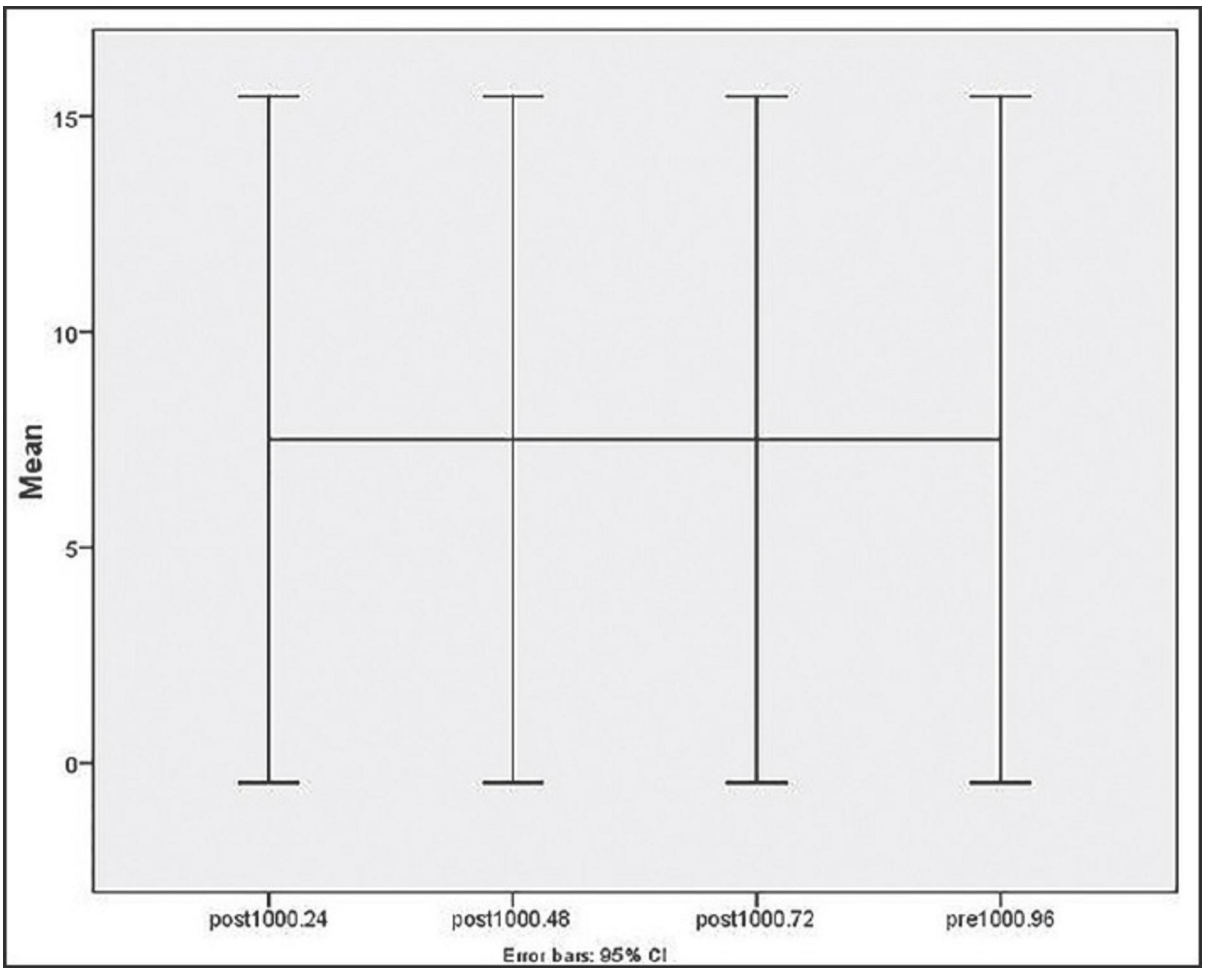
Hearing levels at 250 Hz according to different times after the surgery (PTA)

Figure 2



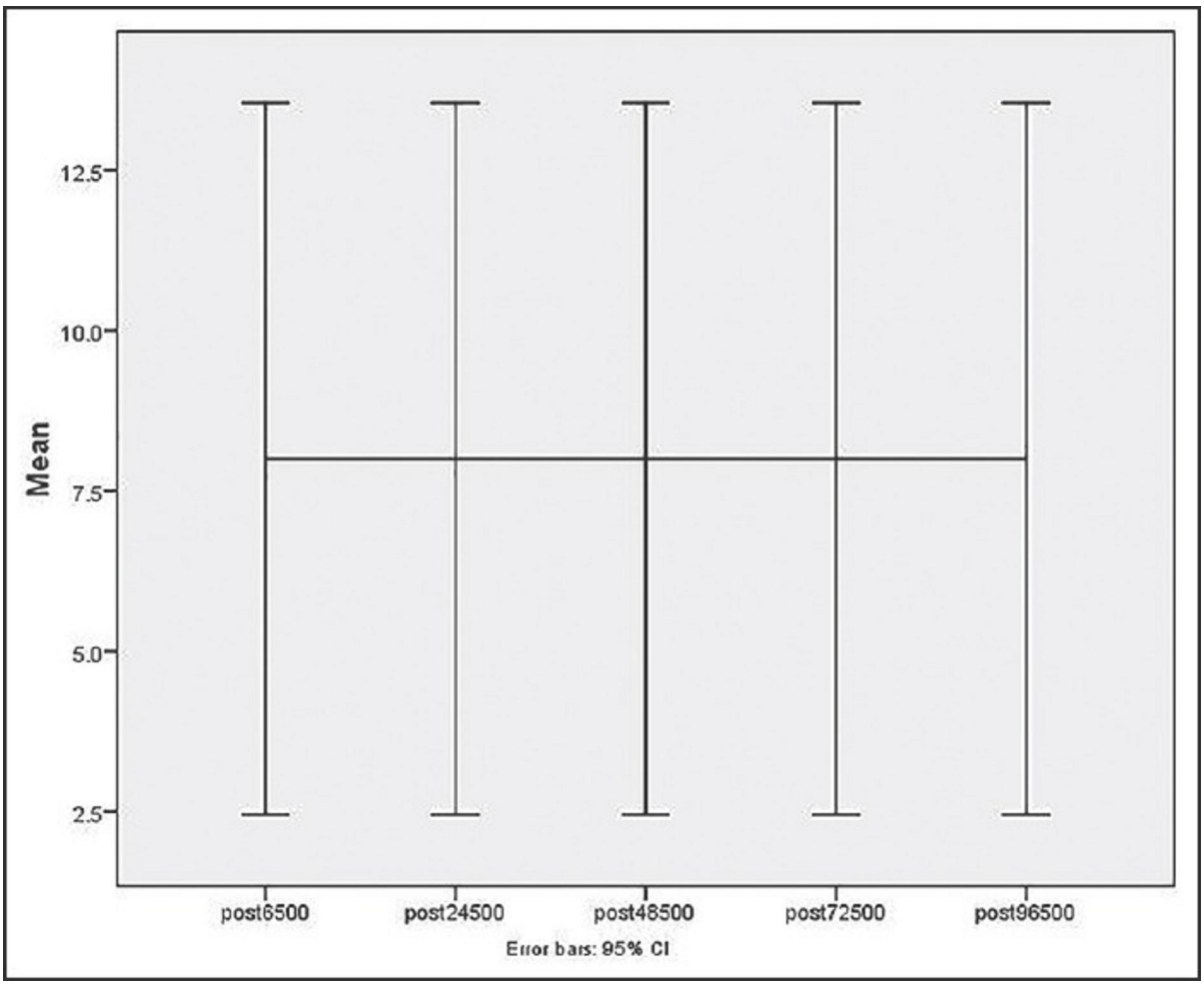
Hearing levels at 500 Hz according to different times after the surgery (PTA)

Figure 3



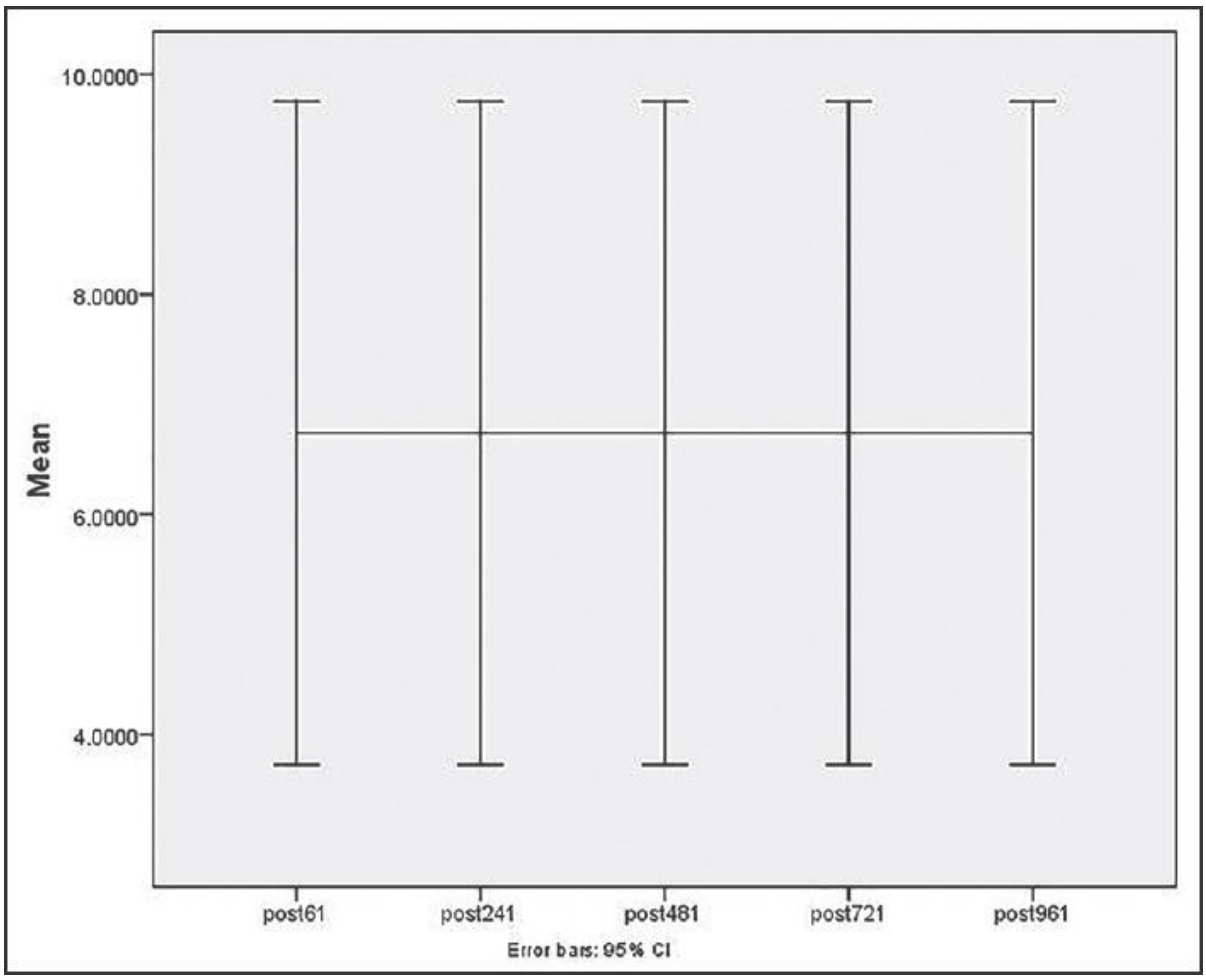
Hearing levels at 1000 Hz according to different times after the surgery (PTA)

Figure 4



Hearing level DPOAE amplitudes in 500 Hz according to different times after the surgery

Figure 5



Hearing level DPOAE amplitudes in 1000 Hz according to different times after the surgery

Table 2

Comparison of hearing loss and number of patients, according to the frequencies in PTA

Frequency	After 24 h	After 48 h	After 72 h	After 96 h
3000 Hz	13	3	0	0
4000 Hz	10	2	0	0
6000 Hz	15	3	1	0
8000 Hz	13	4	1	0

PTA = Pure-tone audiometry

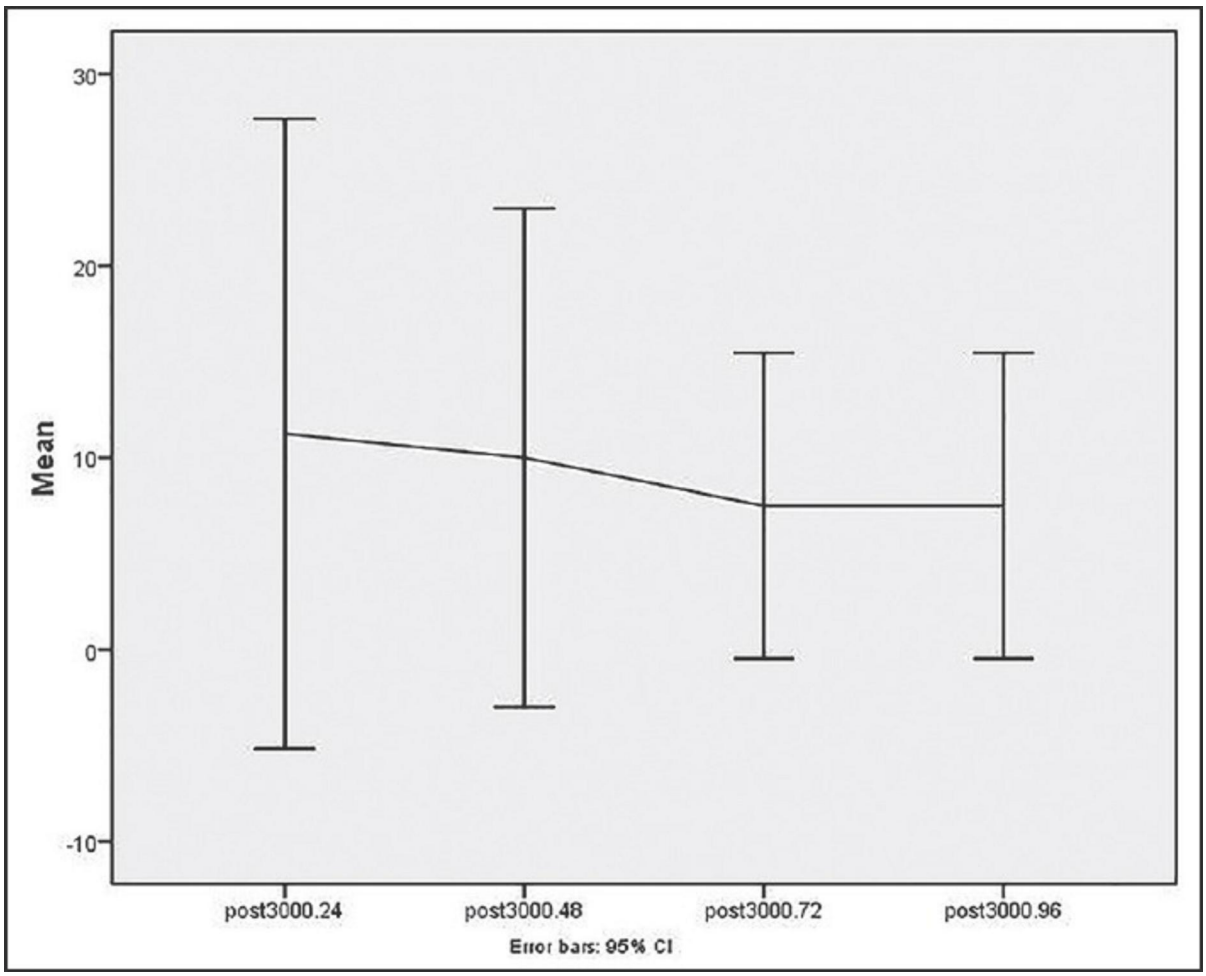
Table 3

Number of patients with postsurgical hearing loss, according to the frequencies in DPOAE

Frequency	After 6 h	After 24 h	After 48 h	After 72 h	After 96 h
2000 Hz	27	21	13	7	0
4000 Hz	26	24	18	10	0
6000 Hz	26	25	19	11	0
8000 Hz	28	27	23	15	0

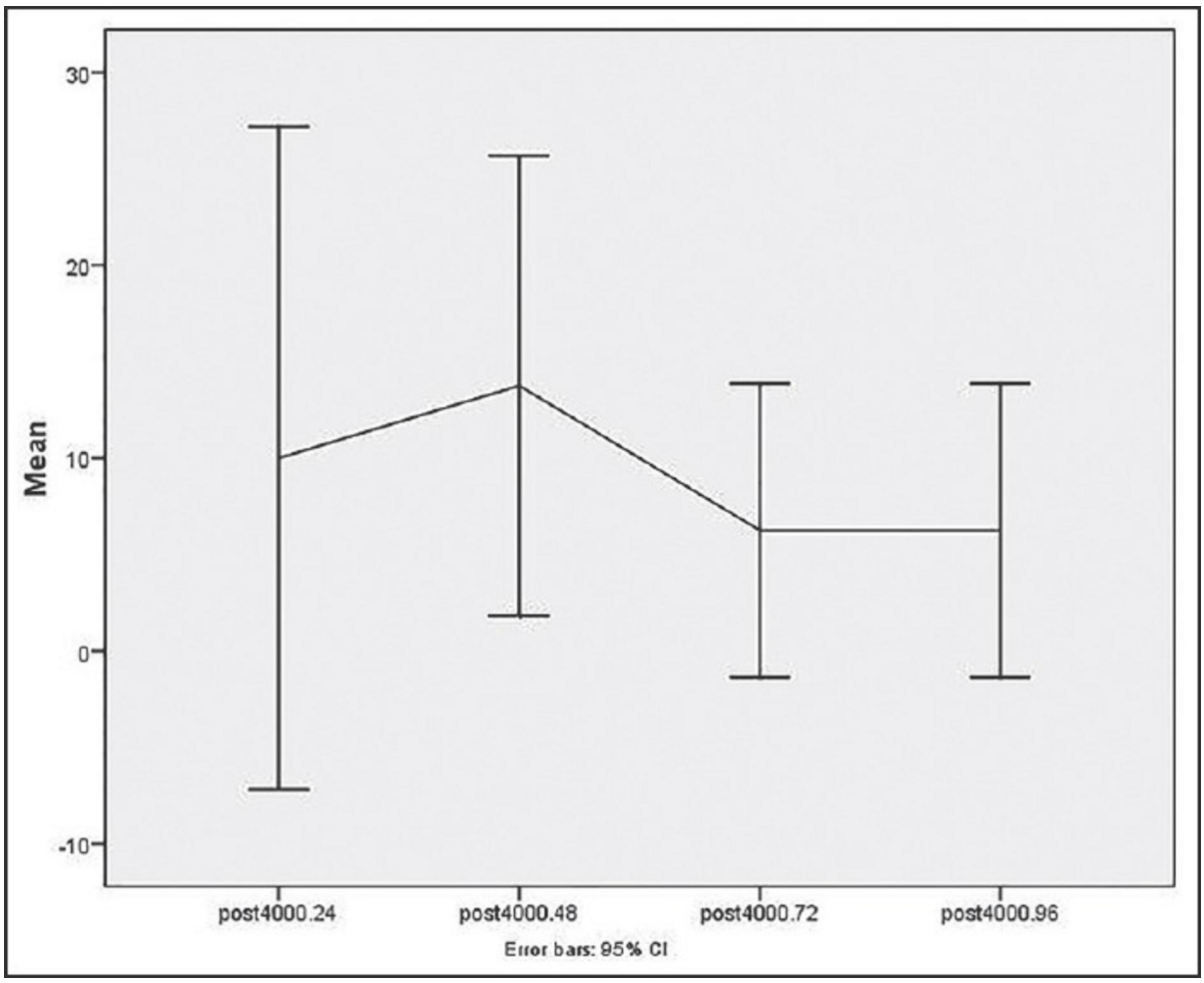
DPOAE = Distortion-product otoacoustic emission

Figure 6



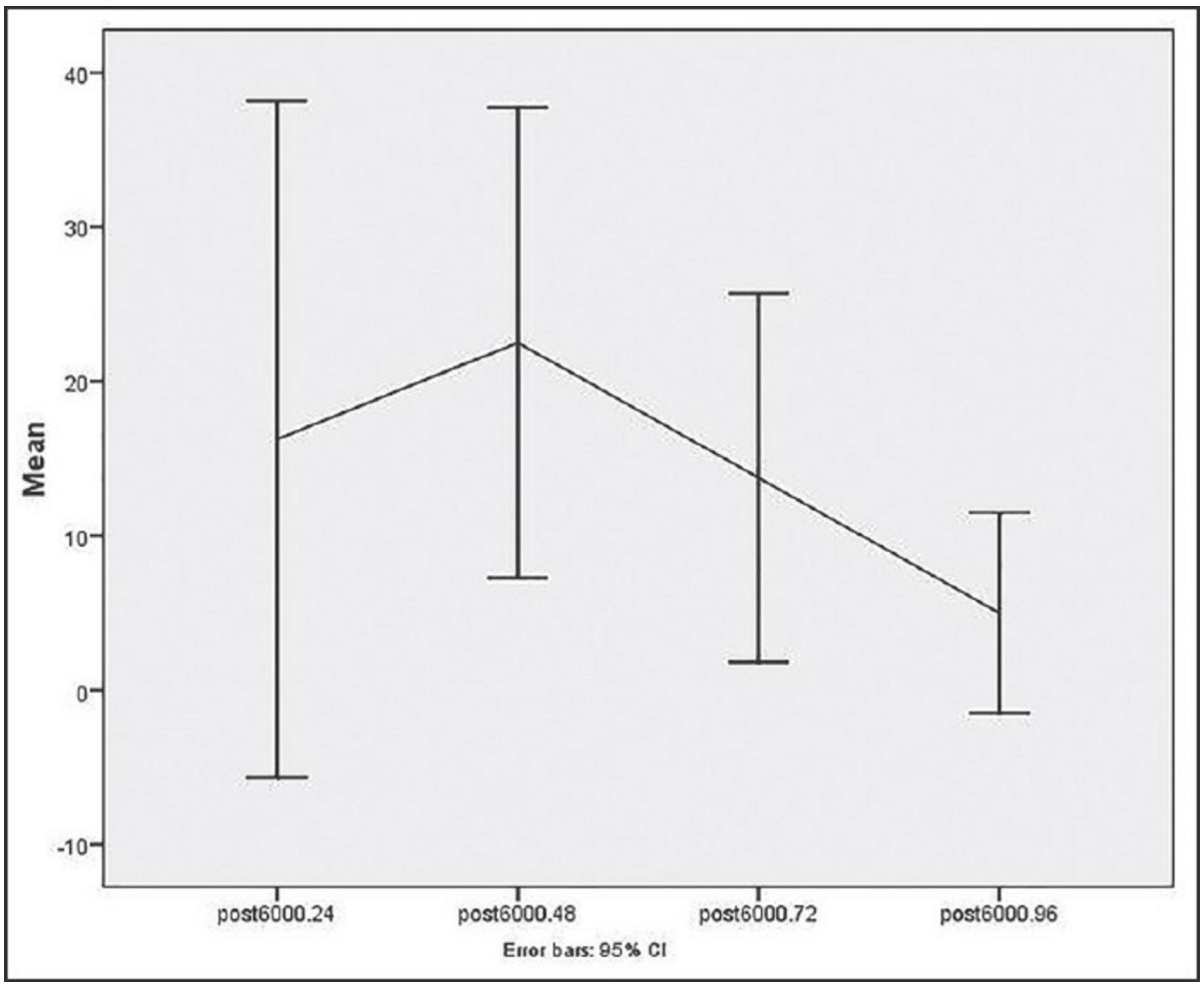
Hearing levels at 3000 Hz according to different times after the surgery (PTA)

Figure 7



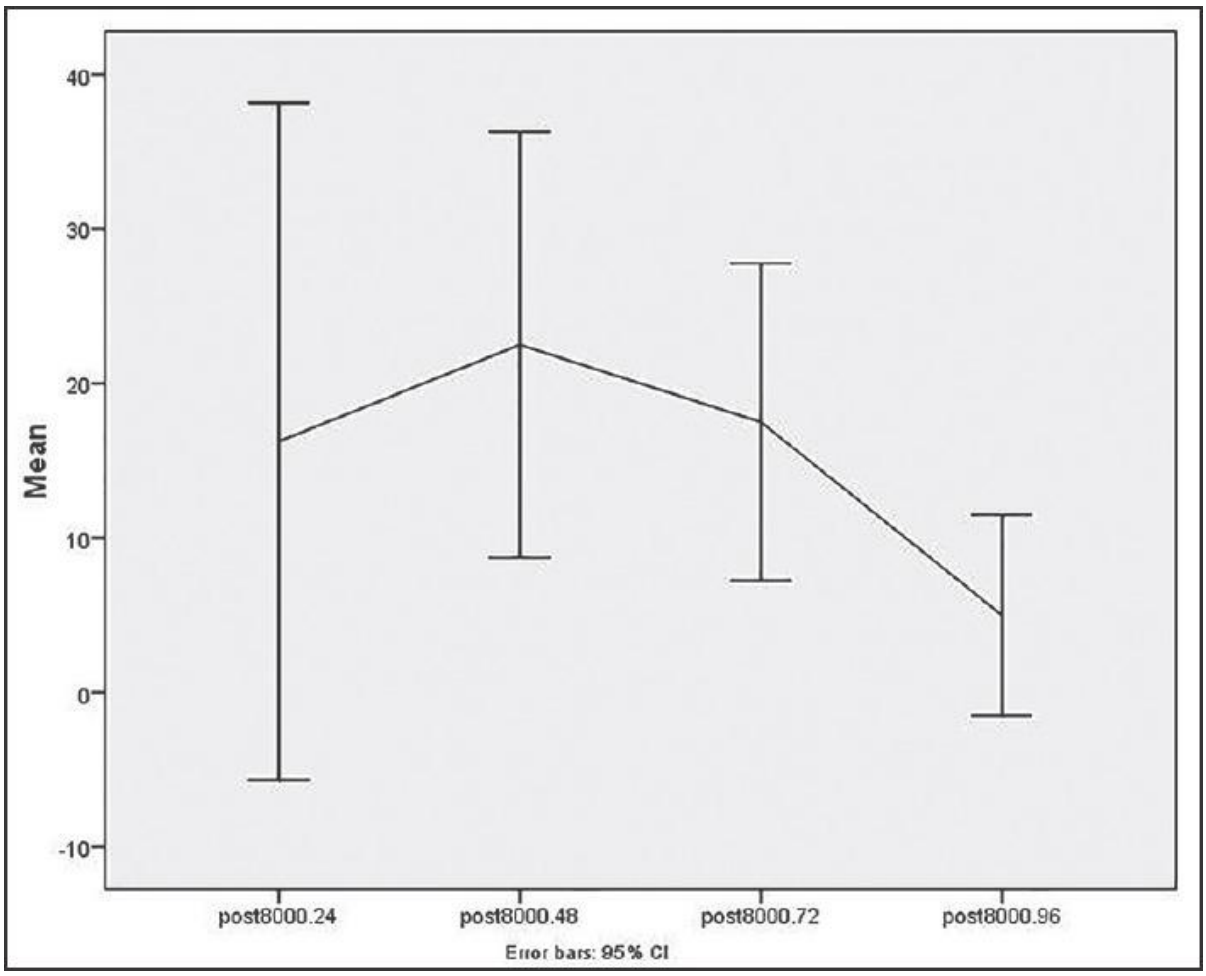
Hearing levels at 4000 Hz according to different times after the surgery (PTA)

Figure 8



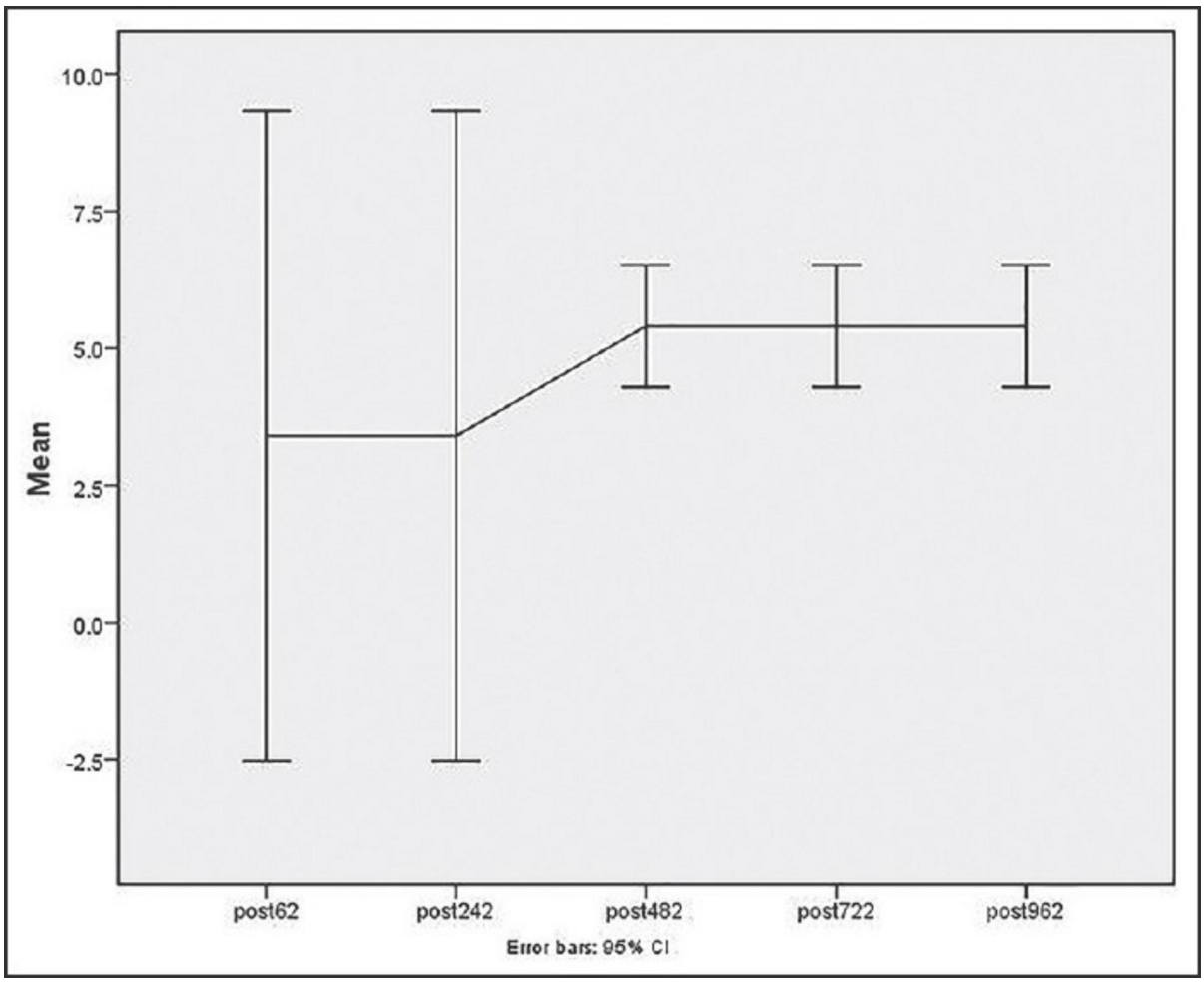
Hearing levels at 6000 Hz according to different times after the surgery (PTA)

Figure 9



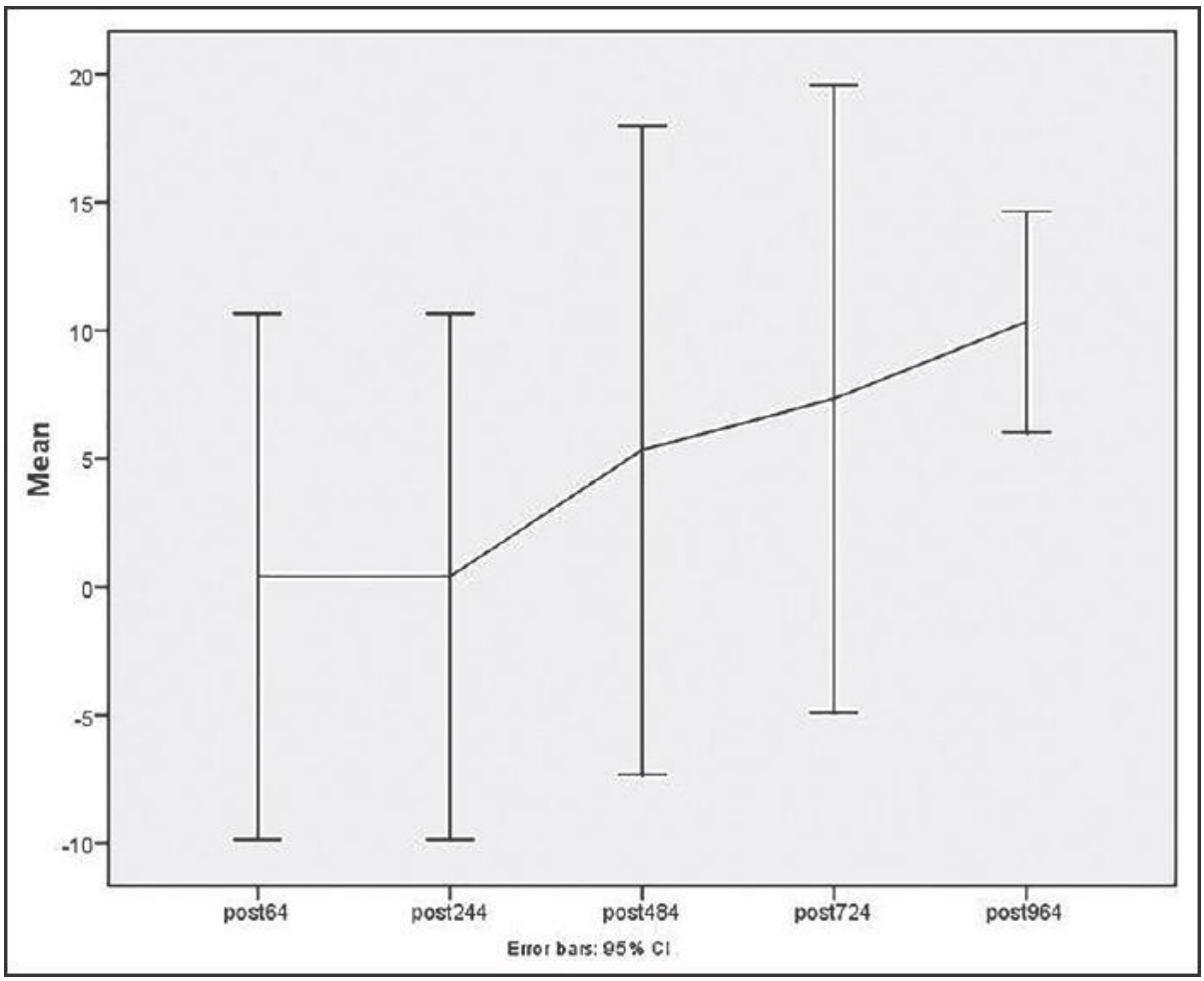
Hearing levels at 8000 Hz according to different times after the surgery (PTA)

Figure 10



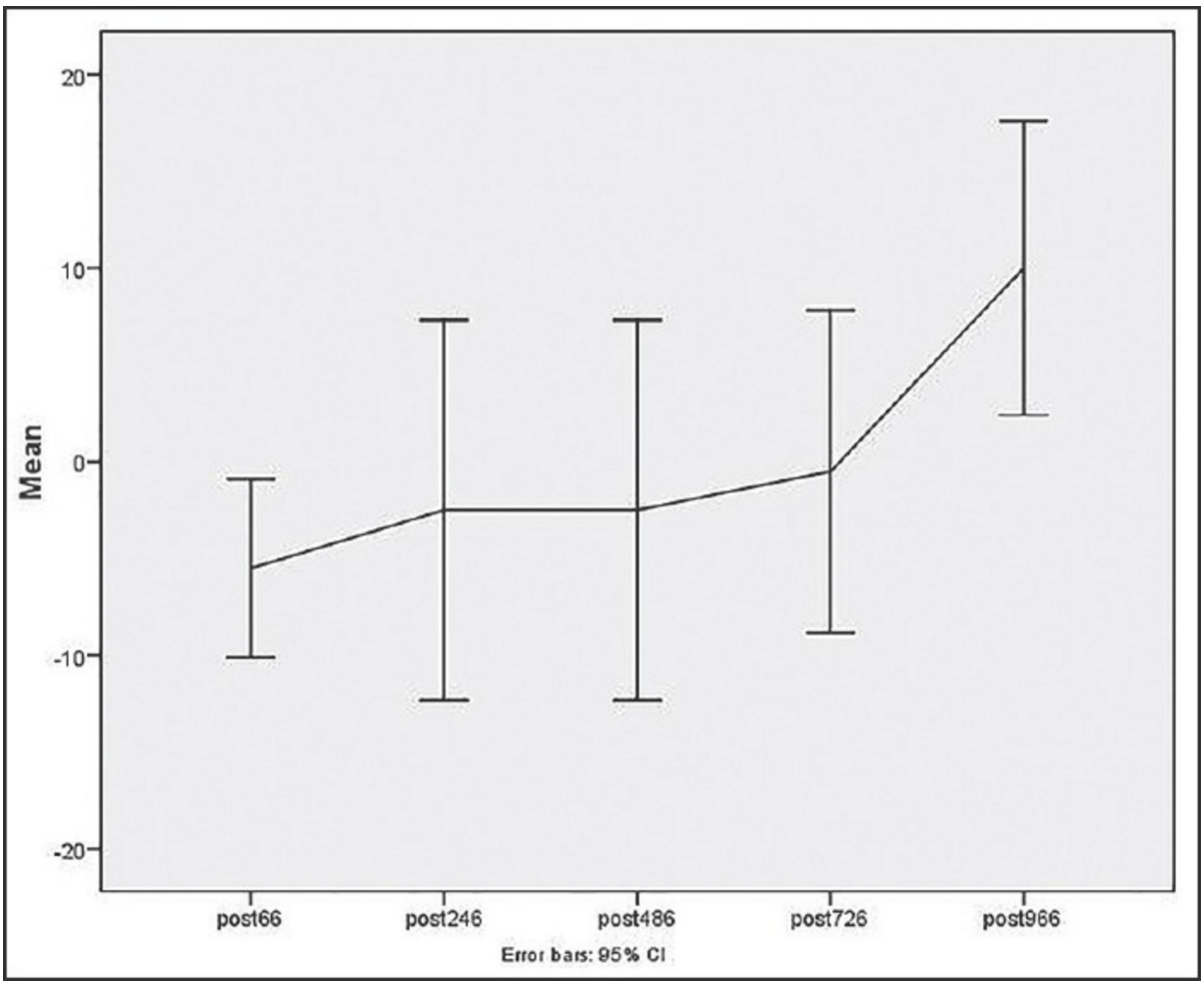
Hearing level DPOAE amplitudes in 2000 Hz according to different times after the surgery

Figure 11



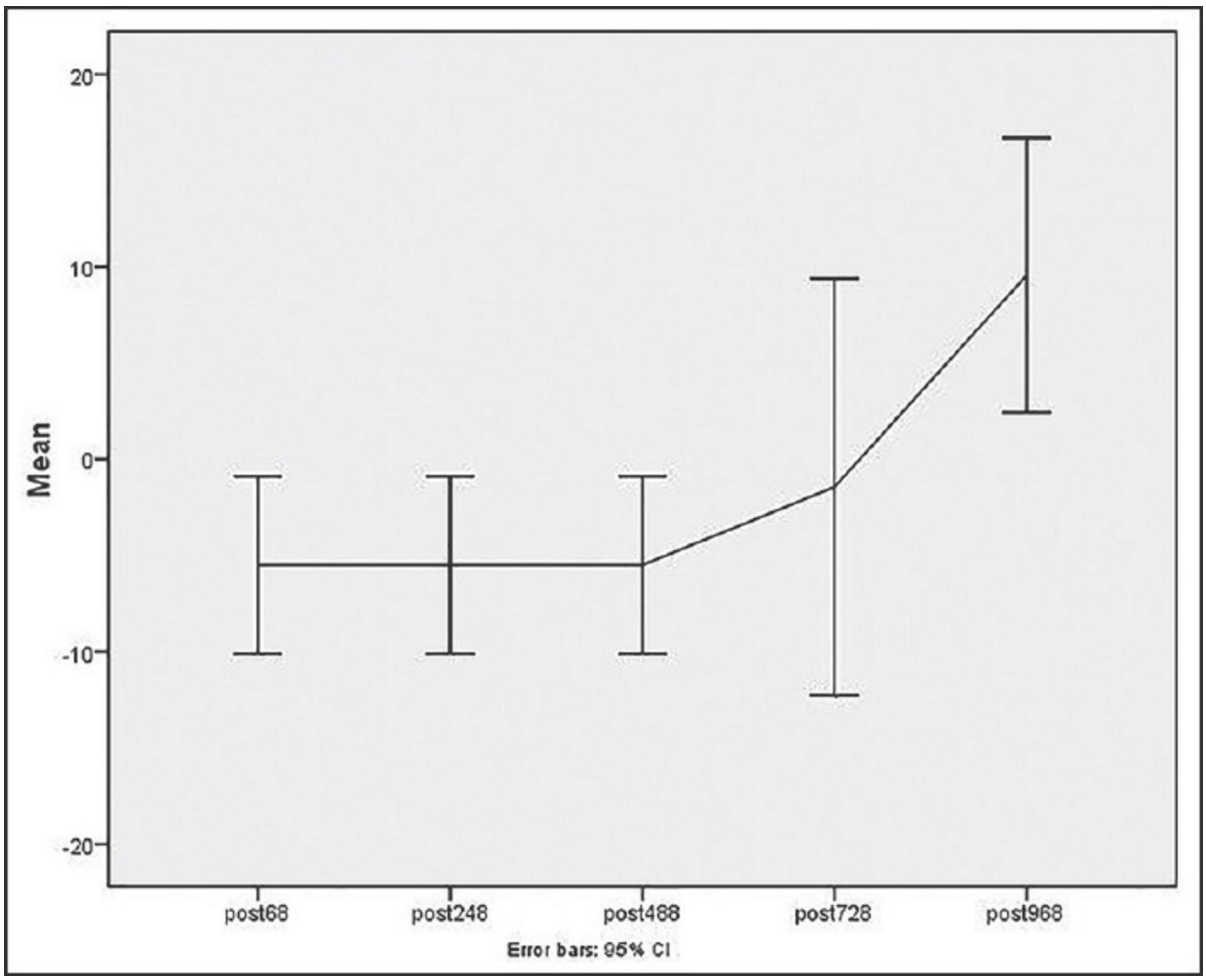
Hearing level DPOAE amplitudes in 4000 Hz according to different times after the surgery

Figure 12



Hearing level DPOAE amplitudes in 6000 Hz according to different times after the surgery

Figure 13



Hearing level DPOAE amplitudes in 8000 Hz according to different times after the surgery

Table 4

Comparison of hearing loss amplitudes (SPL) of patients, according to the frequencies in DPOAE

Pre- and postoperation difference	Paired difference		*P* value
	Mean SPL	SD	
After 24 h AT 2 kHz	–1.07	3.4	0.01
After 24 h AT 4 kHz	–10.18	7.8	0.00
After 24 h AT 6 kHz	–13.6	10.5	0.00
After 24 h AT 8 kHz	–17.7	9.8	0.00
After 48 h AT 2 kHz	–10.5	8	0.00
After 48 h AT 4 kHz	–3.22	6.5	0.01
After 48 h AT 6 kHz	–6.26	9.5	0.001
After 48 h AT 8 kHz	–7.7	9.6	0.00
After 72 h AT 4 kHz	–1	3.8	0.03
After 72 h AT 6 kHz	–3.5	7.6	0.01
After 72 h AT 8 kHz	–3.66	6.6	0.05

SPL = Sound pressure level; DPOAE = Distortion-product otoacoustic emission; SD = Standard deviation

Table 5

Mean hearing loss threshold pre- and postoperation difference (dB) of patients, according to the frequencies in PTA

Pre- and postoperation difference	Paired difference		*P* value
	Mean dB	SD	
AFTER 24 h AT 2 kHz	0.71	2.95	0.212
After 24 h AT 3 kHz	2.68	6	0.02
After 24 h AT 4 kHz	3.04	5.15	0.00
AFTER 24 h AT 6 kHz	7.79	8.5	0.00
After 24 h AT 8 kHz	10.98	8.4	0.00
AFTER 48 h AT 3 kHz	1.42	4.5	0.1
After 48 h AT 4 kHz	1.6	4.9	0.09
After 48 h AT 6 kHz	6	10.5	0.00
After 48 h AT 8 kHz	5.3	9.4	0.00
After 72 h AT 3 kHz	-2.3	4	0.06
After 72 h AT 4 kHz	1.33	5	0.33
After 72 h AT 6 kHz	2.7	5	0.1
After 72 h AT 8 kHz	4.7	8	0.04

PTA = Pure-tone audiometry; SD = Standard deviation