ORIGINAL ARTICLE

Assessment of hearing sequelae in individuals tested post-trauma

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ABSTRACT

BACKGROUND: Over 5% of the global population (430 million people) require rehabilitation for hearing loss. Individuals with hearing impairments face significant challenges in business, daily life, and social participation. Hearing loss (HL) and other permanent physical and sensory disabilities escalate dramatically in cases with brain damage and temporal bone trauma associated with head injuries. This study aims to identify the significant risk factors for hearing loss following head trauma, utilizing current data, and discuss the findings in the context of the literature. This could contribute to the development of standard approaches for assessing such cases.

METHODS: This retrospective study reviewed files and reports from individuals assessed for hearing loss at Dokuz Eylül University Faculty of Medicine, Department of Forensic Medicine. The study included cases that applied at least 12 months post-trauma, between January 1, 2016, and December 31, 2022, after their recovery process was completed. Sociodemographic data, types of temporal bone fractures, initial otoscopic examination findings, presence or absence of intracranial injury, type of hearing loss, and audiometry test results for air and bone conduction pure tone threshold averages were evaluated. Data analysis was conducted using SPSS 26.0 (Statistical Package for the Social Sciences).

RESULTS: Out of 244 cases, 177 (72.5%) were male and 67 (27.5%) were female. It was observed that the majority of trauma cases occurred in the 19-40 age group (49.2%; n=120). In the initial otoscopic examinations post-trauma, otorrhagia/otorrhea was the most common finding, both as an isolated symptom (n=59, 24.2%) and when accompanied by other symptoms. No temporal bone fractures were detected in 43 cases (17.6%). Longitudinal fractures were found in 141 cases (57.8%), transverse fractures in 48 (19.7%), and mixed-type fractures in 12 (4.9%). The statistical difference in air conduction and bone conduction pure tone threshold averages between groups with and without intracranial injury was significant ($p<0.001$).

CONCLUSION: Post-traumatic examinations should employ a multidisciplinary approach, adhering to standard medical improvement and assessment timelines. It is essential to verify whether each patient's medical improvement process has reached its maximum potential. We believe that adhering to these recommendations and utilizing standardized classifications for hearing loss will prevent the loss of rights.

Keywords: Post-traumatic hearing loss; temporal bone fracture; intracranial injury; otorrhagia/otorrhea; pure tone treshold.

INTRODUCTION

Head traumas are a major cause of death and disability among young people worldwide, particularly in urban areas. They account for 50% of trauma-related fatalities. Annually, approximately 10 million people worldwide are hospitalized due to head trauma, and 57 million have experienced at least one head trauma-related hospitalization in their medical history.

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Physical symptoms manifest in 10-15% of those with severe head injuries, varying with the location and severity of the injury. Hearing loss (HL), dizziness, disorders in walking and speech, blurred vision, diplopia, photophobia, phonophobia, diminished taste and smell (ageusia-anosmia), tinnitus, and other permanent physical and sensory disabilities are notably prevalent in individuals with brain damage from head trauma.[1-6]

Specifically, the risk of developing hearing loss is 21-25 times higher in patients with traumatic brain injury.[7]

More than 5% of the world's population (430 million people) requires rehabilitation for hearing loss. This figure is expected to surpass 700 million by 2050. Individuals with hearing impairments encounter major obstacles in business, daily, and social life. According to the World Health Organization (WHO), a person is considered to have normal hearing if the hearing threshold in both ears is 20 dB or better. Hearing loss can be mild, moderate, severe, or profound, and may affect either one ear or both ears.[8]

It is estimated that hearing loss occurs in approximately 24-81% of patients with temporal bone trauma.[9] Temporal bone fractures are categorized as either transverse or longitudinal, depending on the orientation of the fracture line relative to the petrous process.[10] Longitudinal fractures typically run through the middle ear, parallel to the external auditory canal, and extend to the foramen ovale, in front of the otic capsule, and alongside the petrous process. Transverse fractures, on the other hand, cut perpendicularly across the petrous ridge, extending from the foramen magnum through the petrous pyramid and often involve the internal auditory canal, terminating at the foramen spinosum or lacerum. Longitudinal fractures usually result from lateral impacts to the temporal or parietal areas of the skull, while transverse fractures generally occur from frontal or occipital impacts. Fractures that begin longitudinally may shift to a diagonal path, and those starting diagonally may align longitudinally. These types of fractures are known as mixed fractures.[11]

The primary mechanism of hearing loss from these fractures is mechanical damage to the middle and inner ear structures.[12,13] Sensorineural hearing loss is more prevalent, especially in cases where the otic capsule is damaged.[14,15] Nonetheless, hearing loss can also arise without any fractures in the temporal bone, due to injuries to the peripheral or central auditory pathways.[16]

Hearing loss is typically categorized into three types: conductive hearing loss (CHL), sensorineural hearing loss (SNHL), and mixed-type hearing loss.[17] Conductive hearing loss results from damage to the external ear, while sensorineural hearing loss stems from damage to the inner ear or central auditory pathway.[18] Post-traumatic conductive hearing loss can occur due to disruptions in the bone chain, and post-traumatic sensorineural hearing loss may result from inner ear conditions such as labyrinthine hemorrhage or perilymphatic fistula.[19]

For a decrease in the function of a sense, organ system, or organ to be deemed permanent and considered a "sequela," it must have reached maximum medical improvement, meaning the condition has stabilized. This term implies that no significant change is expected within the next year, with or without medical treatment.[20] Thus, in routine forensic medicine, the presence of sequelae related to the injury site is assessed with a control examination performed at least one year after the trauma.

The frequency range on the audiogram where hearing loss has the most significant impact is between 3 kHz and 6 kHz. The loss often becomes apparent first around 4 kHz.[21] In some countries, hearing loss definitions are based on pure-tone threshold values at 1, 2, and 3 kHz, or 0.5, 1, 2, and 3 kHz.[22,23] According to the American Medical Association's (AMA) Evaluation of Permanent Impairment Guide, hearing loss is defined as the average pure-tone threshold values at 500, 1000, 2000, and 3000 Hz in one ear exceeding 25 dB.[20]

The WHO first categorized hearing impairment in 1986, with several updates to this classification, the latest in 1991 (Table 1).[24,25] In 2008, the Global Burden of Disease Expert Group considered the WHO classification of hearing impairment for its 2010 study, leading to a new classification recommendation (Table 2).[24,26]

The objective of this study is to identify the significant risk factors for hearing loss following head trauma using current

Table 1. World Health Organization (WHO) grades of hearing impairment

Grade of impairment	Corresponding audiometric ISO value (a,b)
0: no impairment	25 dB or better
1: slight impairment	26-40 dB
2: moderate impairment	41-60 dB
3: severe impairment	61-80 dB
4: profound impairment including deafness	81 dB or greater

dB: Decibel; Hz: Hertz; ISO: International organization for standardization; m: Meter; WHO: World. a In the better ear. b Average of 500, 1000, 2000 and 4000 Hz.

Table 2. Grades of hearing impairment recommended by the Global Burden of Disease Expert Group on hearing loss

Category	Pure-tone audiometry (a,b)
Normal hearing	-10 to 4.9 dB hearing level
	5.0 to 19.9 dB hearing level
Mild hearing loss	20.0 to 34.9 dB hearing level
Moderate hearing loss	35.0 to 49.9 dB hearing level
Moderately severe hearing loss	50.0 to 64.9 dB hearing level
Severe hearing loss	65.0 to 79.9 dB hearing level
Profound hearing loss	80.0 to 94.9 dB hearing level
Complete or total hearing loss	95.0 dB hearing level or greater
Unilateral	<20.0 dB hearing level in the better ear
	35.0 dB hearing level or greater in the worse ear

dB: Decibel; Hz: Hertz;. a In the better ear. b Average of 500, 1000, 2000 and 4000 Hz.

data and discuss these findings in the context of the literature. This will contribute to developing standardized approaches for evaluating such cases.

MATERIALS AND METHODS

We retrospectively examined the files and reports of 244 cases who were assessed for hearing loss at Dokuz Eylul University Faculty of Medicine, Department of Forensic Medicine. These cases had applied at least 12 months after experiencing trauma, between January 1, 2016, and December 31, 2022, and their improvement processes were complete. We assessed sociodemographic data, the cause of trauma, types of temporal bone fractures, initial otoscopic examination findings, presence or absence of intracranial injury, audiometry test results for air and bone conduction pure tone threshold averages, degree of hearing loss according to WHO and Global Burden of Disease (GBD) Expert Group classifications, and the type and side of hearing loss. This research was conducted with approval from the Dokuz Eylul University Faculty of Medicine Ethics Committee (Date: 18. 10. 2023, Decision No: 2023/33-14).

Statistical Analysis

Statistical analysis was performed using SPSS 26.0 (Statistical Package for the Social Sciences). We conducted descriptive analyses, reporting means and standard deviations for continuous variables and percentages for categorical variables. We analyzed categorical dependent and independent variables using the Pearson Chi-square and Fisher-Freeman-Halton Exact Test. Continuous variables conforming to normal distribution and measured in two independent groups were analyzed using the independent sample t-test. Continuous variables conforming to normal distribution and measured in more than two independent groups were analyzed with a one-way Analysis of Variance (ANOVA) test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Of the 244 cases, 177 (72.5%) were male, and 67 (27.5%) were female. The average age was 31.9±15.4 years (range 2-71 years). The average age for women was 34.4±17.2 years, while for men, it was 31.0±14.6 years. Analysis by age groups showed that trauma cases were most common in the 19-40 age group (49.2%; n=120) (Fig. 1). When examining the causes of trauma, the distribution was as follows: traffic accidents inside vehicles (TAIV) accounted for 72 cases (29.5%), motorcycle accidents (MA) for 69 cases (28.3%), traffic accidents outside vehicles (TAOV) for 53 cases (21.7%), assaults for 23 cases (9.4%), bicycle accidents (BA) for 16 cases (6.6%), occupational accidents (OA) for 8 cases (3.3%), and blast effects for 3 cases (1.2%) (Fig. 2).

Considering the average age of cases according to the cause of trauma, a statistically significant difference was noted between the average age of cases injured in non-traffic accidents (36.23±13.6) and those in motorcycle accidents (28.07±13.4) ($p<0.05$).

In the initial otoscopic examinations post-trauma, otorrhagia/otorrhea was the most common finding, occurring both in

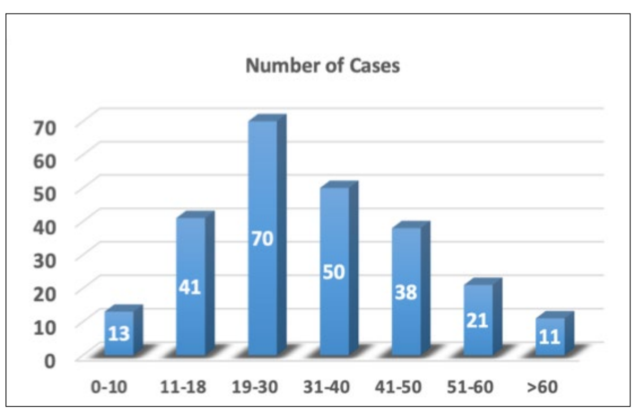

Figure 1. Distribution of cases by age range.

Table 3. Distribution of otoscopic examination findings by cause of trauma

	Causes of Trauma						
Otoscopic Examination Findings	**TAIV%**	**TAOV%**	**MA%**	**BA%**	**ASSAULT%**	**OA%**	**BLAST%**
Hemotympanum	13.89	9.44	13.04	12.5	21.79	0	0
TM perforation	11.11	3.77	7.24	12.5	43.48	25	33.33
TM edema	11,11	15.09	2.90	6.25	43.48	25	0
EAC injury	11,11	15.09	10.14	25	17.40	25	0
Otorrhagia/Otorrhea	23.61	3.19	27.56	31.25	4.35	12.5	0
Ossicular chain injury	5.56	1.89	11.59	0	0	12.5	0
Multipl findings	9.72	15.09	17.39	6.25	0	0	33.33
Other	13.89	9.44	10.14	6.25	0	0	33.33

TAIV: Traffic accidents inside vehicle; TAOV: Traffic accidents outside vehicle; TM: Tympanic membrane; EAC: External auditory canal; MA: Motorcycle accident; BA: Bicycle accident; OA: Occupational accidents.

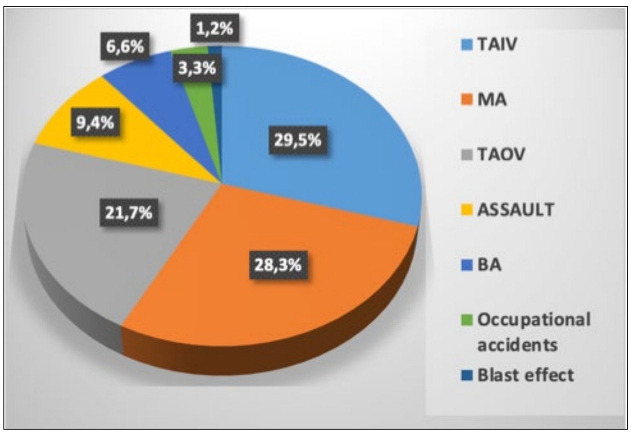

Figure 2. Distribution of cases by cause of trauma.

Table 4. Distribution of hearing loss types

Hearing loss type	**n**	**%**
SNHL	110	45.1
MIXED	34	13.9
CHL	29	11.9
No hearing loss	71	29.1

SNHL: Sensorineural HL; CHL: Conductive hearing loss.

isolation (n=59, 24.2%) and in conjunction with other symptoms, followed by hemotympanum (n=31, 12.7%). Otorrhagia/otorrhea was most frequently detected in the first otoscopic examination across all types of traffic accidents, while tympanic membrane perforation was predominantly found in cases of assault (n=10, 43.48%) (Table 3).

Hearing loss was unilateral in 153 cases (62.7%) and bilateral in 20 cases (8.2%). No hearing loss was detected in 71 cases (29.1%). A significant extent of hearing loss was found in cases injured in traffic accidents outside the vehicle (n=37, 69.8%) and motorcycle accidents (n=56, 81.2%). Conversely, hearing loss occurred less frequently in cases injured for reasons other than traffic accidents (n=21, 61.8%). A statistically significant correlation was found between the occurrence of hearing loss and the cause of trauma ($p<0.001$).

Regarding the distribution of hearing loss types, SNHL was the most common (n=110, 45.1%), followed by mixed HL (n=34, 13.9%), and CHL (n=29, 11.9%) (Table 4).

Overall, the average air conduction pure tone threshold was 44.89±28.40 dBHL, and the bone conduction pure tone threshold averaged 39.66±26.20 dBHL.

While no temporal bone fractures were detected in 43 cases (17.6%), longitudinal fractures were observed in 141 cases (57.8%), transverse type fractures in 48 cases (19.7%), and mixed type fractures in 12 cases (4.9%). Air conduction and bone conduction pure tone threshold averages were higher in cases with transverse type temporal bone fractures compared to those with longitudinal fractures. In cases without temporal bone fractures, both air conduction and bone conduction pure tone threshold averages were significantly lower than in cases with fractures. Statistically significant differences in air conduction and bone conduction pure tone threshold averages were noted between groups with and without temporal bone fractures ($p<0.001$).

Intracranial injuries were present in the majority of cases (n=135, 55.3%). Fifty-five cases (22.5%) had more than one type of intracranial injury. There were 22 cases (9%) each with subarachnoid hemorrhage and epidural hematoma, 20 cases (8.3%) with subdural hematoma, 4 cases (1.6%) with parenchymal injury, and 12 cases (4.9%) with other types of injuries. Among the cases with intracranial injuries, 114 (84.4%) experienced hearing loss, while in 50 cases (70.4%) without intracranial injuries did not have hearing loss. A statistically significant difference was found between the groups with and without intracranial injuries in terms of hearing loss occurrence (p<0.001).

For cases with intracranial injury, air conduction and bone conduction pure tone threshold averages were 51.93±26.21 dBHL and 46.95±25.14 dBHL, respectively. For cases without intracranial injury, these averages were 36.17±28.69 dBHL and 30.63±24.74 dBHL. The difference in air conduction and bone conduction pure tone threshold averages between groups with and without intracranial injuries was statistically significant (p<0.001).

According to the WHO classification, 71 cases (29.1%) had first-degree hearing loss and 39 cases (16%) had third-degree hearing loss. According to the GBD Expert Group classification, the most common type of hearing loss was unilateral (n=153, 62.7%), and among the 6 cases with bilateral hearing loss, all were classified as having moderately severe hearing loss. The detection rate of third and fourth-degree hearing loss according to the WHO classification was found to be higher in cases with intracranial injury than in those without.

Facial paralysis was detected in 37 (15.2%) of all trauma cases, with 30 cases (12.3%) exhibiting peripheral paralysis and 7 cases (2.9%) showing central paralysis.

DISCUSSION

Head traumas are among the leading reasons for assessments of sequelae after injury.[27,28] A variety of sequelae may remain in cases of head trauma, one of which is hearing loss. This is due to the numerous anatomical structures and conduction pathways related to hearing located in the head region.

Although the frequency of head trauma-related injuries varies by gender, studies show that it occurs more frequently in men. In our study, 72.5% of the cases were male and 27.5% were female. This finding aligns with the literature, including a study by Çökük A. et al., which reported that 63% (n=3,276) of 5,200 patients presenting to the emergency department due to head trauma were male.[29] Similarly, a study conducted by Podoshin L. et al., which examined cases of hearing loss following head trauma, found that 77.5% (n=307) of the cases were male. Another study by Shangkuan WC et al. reported a similar finding, with 61.63% male cases.[7,30] In research by Alpsoy MY. et al., which involved 506 cases of post-traumatic hearing loss, it was found that males cases comprised 79.4% (n=402) of the cases.[6] This trend may be attributed to men being more frequently exposed to various risks due to their higher levels of activity in both professional and social settings. Our study's findings align with these observations from the literature.

In terms of age distribution, trauma cases were most frequent in the 19-40 age group, accounting for 49.2% of cases (n=120). Işık HS. et al., in their study analyzing 954 adult cases with head trauma, reported that the majority of cases were between the ages of 21-40 (n=395, 41.4%). The findings in our study parallel the literature.[7,31,32]

Research into the causes of head injuries indicates that traffic accidents (49.7% and 61.3%), falls (35.2%, 18.6%, and 36.4%), and assaults (24.6%) are the top three contributors.[33,34,35] Alpsoy MY. et al. reported that traffic accidents outside the vehicle were predominant (n=256, 52.4%).[6] Similarly, in our study, traffic accidents led (n=210, 86.1%).

In our study, the average age of individuals injured in motorcycle accidents was significantly lower than those injured in non-traffic accidents, a difference that was statistically significant (p<0.05). Various studies have noted that most motorcycle accident victims (n=148, 36.5%) are aged 16-25, and 65.8% (n=267) are under 35 years old.[36] Our findings align with these observations.

Consistent with the literature, the most frequent finding in the initial post-traumatic otoscopic examinations was otorrhagia/otorrhea, both isolated and in conjunction with other symptoms.[6,37,38] Tympanic perforation was found in 12.3% of all cases in our study, whereas in cases of assault, this rate was 43.48%.

In a study by Sayın İ. et al., examining the prevalence of ear, nose, and throat pathologies in patients presenting to a health board, SNHL was identified as the most common type of hearing loss, excluding cases of chronic otitis media.[39] In our study, consistent with the literature, we observed that SNHL was the most common type of hearing loss detected after trauma.[6,7,30]

Regarding temporal bone fractures, our study found no fractures in 17.6% of cases, longitudinal fractures in 57.8%, transverse type fractures in 19.7%, and mixed type fractures in 4.9%. These figures compare to findings by Alpsoy MY et al., where 60.4% were longitudinal, 20.8% transverse, and 18.8% mixed.[6] Amin Z. et al. reported detecting longitudinal fractures in 67.4%, transverse fractures in 8.7%, mixed fractures in 13.0%, and oblique fractures in 10.9% of head trauma patients.[40] Our findings are consistent with this distribution in the literature.

In cases without temporal bone fractures, the air conduction and bone conduction pure tone threshold averages were significantly lower than in cases with temporal bone fractures. The difference in air conduction and bone conduction pure tone threshold averages between the groups with and without temporal bone fracture was statistically significant (p<0.001).

Literature indicates that diffuse axonal damage or coup-contrecoup lesions may occur from the whipping movement (acceleration-deceleration or rotational movement) during accidents.[41] In our study, intracranial pathology was detected in 55.3% of the cases, aligning with other studies in the literature. The percentage of cases with more than one intracranial finding was 22.5%. In comparison, Alpsoy MY et al. reported rates of 73.1% and 40.7%, respectively.[6] A statistically significant difference was observed in the incidence of hearing loss between groups with and without intracranial injuries (p<0.001). Similarly, the difference in air conduction and bone conduction pure tone threshold averages between groups with and without intracranial injuries was statistically significant (p<0.001).

CONCLUSION

In cases assessed for hearing sequelae after head trauma, the presence of sequelae varies based on several factors, including the type of trauma, initial otoscopic findings post-trauma, the presence of temporal bone fractures, intracranial injuries, and the time elapsed between the trauma and the hearing test. As authors, we believe that further studies are necessary to determine the average medical improvement time based on the initial examination findings in patients who have suffered head trauma and are being assessed for hearing sequelae. Standard guidelines should be developed accordingly. By doing so, we believe that the time between the final examination for hearing sequelae and the trauma can be standardized. Furthermore, it is necessary to take a detailed history that questions the condition before the incident, conduct appropriate physical examinations by otorhinolaryngology and neurology clinics, and perform radiological imaging of the injured area to establish the causal connection between the trauma and hearing loss. We are of the opinion that adhering to these recommendations and utilizing standardized classifications for hearing loss will help prevent the loss of rights.

Ethics Committee Approval: This study was approved by the Dokuz Eylul University Faculty of Medicine Ethics Committee (Date: 18.10.2023, Decision No: 2022/33-14).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travma sonrası işitme testi yapılan olguların işitme sekeli yönünden değerlendirilmesi

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AMAÇ: Dünya nüfusunun %5'inden fazlası (430 milyon insan) işitme kaybına yönelik rehabilitasyona ihtiyaç duymaktadır. İşitme engelli kişiler gerek iş hayatına katılımda gerekse günlük yaşam ve sosyal katılımda büyük engellerle karşılaşmaktadır. Kafa travması ile ilişkili beyin hasarı ve temporal kemik travması olan vakalarda, işitme kaybı vb. kalıcı fiziksel ve duyusal engeller çok yüksek oranlara çıkmaktadır. Bu çalışmadaki amacımız güncel veriler dahilinde kafa travması sonrası işitme kaybı meydana gelmesinde etkili risk faktörlerinin ortaya konulması ve konunun literatür bilgileri eşliğinde tartışılması ile bu tarz olguların değerlendirilmesinde oluşturulacak standart yaklaşımlara katkı sağlamaktır.

GEREÇ VE YÖNTEM: 01.01.2016-31.12.2022 tarihleri arasında travmadan en az 12 ay sonra, iyileşme süreci tamamlanıp Dokuz Eylül Üniversitesi Araştırma ve Uygulama Hastanesi Adli Tıp Anabilim Dalına başvuran, işitme kaybı açısından değerlendirilip işitme testi yapılan olguların dosyaları ve raporları geriye dönük olarak incelenmiştir. Sosyodemografk veriler, yaralanma türü, işitme kaybı tipi, temporal kemik kırığı tipi, odyometri testi hava ve kemik yolu saf ses ortalamaları, otoskopik muayene bulguları, intrakranial yaralanma olup olmaması vb. bulgular değerlendirilmiştir. Verilerin istatistiksel analizi SPSS 26.0 paket programı kullanılarak yapılmıştır.

BULGULAR: Toplam 244 olgunun, 177'si (%72.5) erkek, 67'si (%27.5) kadındı. Yaş gruplarına göre yapılan analizde; travma vakalarının en sık 19-40 yaş aralığında (%49.2; n=120) olduğu görüldü. Olguların travma sonrası yapılan ilk otoskopik muayenesinde, ilk sırada hem izole (n=59, %24.2) hem de diğer bulguların eşlik ettiği otoroji/otore bulunmaktaydı. Olguların 43'inde (%17.6) temporal kemik kırığı saptanmazken, 141 (%57.8) olguda longitidunal, 48 (%19.7) olguda transvers, 12 (%4.9) olguda ise mixed tip kırık saptandı. Kafa içi yaralanma olan ve olmayan gruplar arasında hava yolu ve kemik yolu saf ses ortalamaları arasındaki fark istatistiksel olarak anlamlıydı ($p<0.001$).

SONUÇ: Olguların travma sonrası muayenelerinin multidisipliner bir yaklaşımla planlanarak; standart iyileşme, muayene süreleri çerçevesinde ve her olgu özelinde iyileşme sürecinin maksimun düzeyde tamamlanıp tamamlanmadığının sorgulanması ile işitme kaybı yönünden oluşturulmuş standart sınıflamalar dahilinde yapılacak değerlendirilmenin hak kayıplarını engelleyeceği görüşündeyiz.

Anahtar sözcükler: Posttravmatik işitme kaybı; temporal kemik kırığı; intrakranial yaralanma; otoraji/otore; saf ses ortalaması.

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