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Original Article

Titanium Prostheses for Treating Posttraumatic Ossicular Chain Disruption

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BACKGROUND: Posttraumatic chain disruption may be caused by blunt head trauma, barotrauma, or a penetrating foreign body. In cases of severe damage to the incus, or its absence, a titanium prosthesis is a good option for reconstructing the ossicular chain.

METHODS: A retrospective analysis was performed on 24 cases of posttraumatic ossicular chain disruption that had been treated with a titanium partial or total ossicular replacement prosthesis. Air conduction, bone conduction, and air-bone gap were measured before, 6-12 months after, and more than 2 years after the operation. Hearing thresholds were calculated as the mean of 4 frequencies (0.5, 1, 2, and 4 kHz).

RESULTS: The most common cause of ossicular chain disruption was blunt head trauma due to a traffic accident (9 of 24 cases), and there were also a diverse group of foreign bodies which caused damage. In cases where the incus was absent, or significantly damaged, titanium ossiculoplasties were performed (partial or total ossicular replacement prosthesis depending on the presence of the stapes superstructure). Analysis showed a significant improvement in average air conduction threshold and in air-bone gap after surgery ($P < .05$). Closure of the air-bone gap to within 20 dB was observed in 67% of patients.

CONCLUSIONS: Although posttraumatic ossicular chain disruption is not common, it is suspected whenever conductive hearing loss persists for several months after injury. In such cases, ossiculoplasty with a titanium prosthesis is likely to provide satisfactory audiological results.

KEYWORDS: Titanium prostheses, ossiculoplasty, conductive hearing loss

INTRODUCTION

Posttraumatic ossicular chain disruption may be the result of temporal bone fracture due to blunt head trauma, barotrauma (e.g., an open hand or a ball strike to the auricle), or penetrating trauma. Hearing impairment is said to be of a sensorineural nature when associated with inner ear damage—conductive in cases of middle ear destruction and mixed if both regions are involved.[1] The head trauma patient first requires basic life functions to be secured before hearing improvement can be attempted, recognizing that haemotympanum or eardrum perforation usually resolves spontaneously within weeks or months.[2]

The incus has the most fragile suspension in the middle ear and also has the poorest blood supply, so it is a common locus for ossicular chain disruption.[3] More rarely, there can be stapes arch fracture or sometimes isolated damage to the malleus handle from quick removal of a finger from the external ear canal.[4]

Depending on the degree of dysfunction, different methods have been used to restore damaged ossicular chain continuity. In less severe cases, fibrin glue, a fragment of cartilage, or incus interposition can be used for reconstruction.[2] If the incus is absent or cannot be reused, a titanium prosthesis is a good option for surgical repair.[5] The aim of this study is to analyze clinical findings and

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the results of surgical treatment of posttraumatic ossicular chain disruption involving a titanium partial or total replacement prosthesis (PORP or TORP).

METHODS

The medical histories of 24 patients who underwent PORP or TORP ossiculoplasty due to middle ear trauma between 2013 and 2016 were accessed. In all these cases, a TTP-Vario titanium prosthesis (Kurz GmbH, Dusslingen, Germany) was used. Epidemiological data and audiological results before, 6-12 months after, and more than 24 months after the operation were analyzed. Patients without post-operative audiometry were excluded from the study. Hearing thresholds were calculated as the mean of 4 frequencies (0.5, 1, 2, and 4 kHz) for air conduction (AC), bone conduction (BC), and air-bone gap (ABG). The operation was considered successful if the ABG (difference between air and bone conduction) closed to within 20 dB.

All patients underwent ossiculoplasty under general anesthesia more than 6 months after the injury, the elapsed time ranging from 7 months to 22 years (median 8 years). A circular incision of 6-8 mm in diameter and 5-7 mm away from the tympanic membrane was made in the posterior part of the external ear canal. The tympanomeatal flap was raised and the chorda tympani was separated. Middle ear inspection typically revealed destroyed incus unsuitable for reconstruction and a present and mobile malleus. A dedicated Kurz titanium prosthesis was placed between the malleus handle and the stapes head or, if the stapes superstructure was missing, the stapes footplate was placed (the length of the prosthesis was adjusted to 2.5-3.5 mm or 4.75-5.25 mm, respectively). The connection was strengthened with a thin piece of cartilage (with perichondrium) taken from the ear tragus, which also served for closure of the perforation if present. The external ear canal was filled with packing comprised of cotton soaked with antibiotics and a piece of foil, which was removed after 7 days. Ethics Committee of Institute of Physiology and Pathology of Hearing (Approval no: IFPS:KB/Statement no 18/2021). Written informed consent was obtained from all participants who participated in this study.

Statistical Analysis

The normality assumption of quantitative variables was examined using a Shapiro–Wilk test. A Wilcoxon signed-rank test for 2 related samples was then applied. Test results were reported as significant for $P < .05$. Data analysis was done using IBM SPSS Statistics v.24 (IBM SPSS Corp.; Armonk, NY, USA).

RESULTS

Demographic and clinical data of the patients are shown in Table 1.

Causes of the Ossicular Trauma

The causes of middle ear trauma were divided into 2 groups. The first (n = 16, no direct penetration of the middle ear) group comprised patients who had blunt head trauma due to traffic accident (9 cases) and in 4 other cases from ball strikes, a hand, a substantial fall, or other head trauma. The second group comprised cases of penetrating trauma (n = 8): damage caused by cotton buds (2 cases), self-inflicted airgun shot, fine brush, or pen (1 case each), or other sharp objects (3 cases). The indications for operation were hearing loss and a retraction pocket or perforation.

Table 1. Characteristics of the Patients

		All Patients (n = 24)
Age	Range	4-62
	M (SD)	38.33 (12.19)
Sex	Male	15 (62.5)
	Female	9 (37.5)
Operated ear	Right	11 (45.8)
	Left	13 (54.2)
Type of ossiculoplasty	TORP	12 (50.0)
	PORP	12 (50.0)
Cholesteatoma	Absent	22 (91.7)
	Present	2 (7.3)
Retraction pocket	Absent	17 (70.8)
	Present	7 (29.2)
Perforation	Absent	14 (58.3)
	Present	10 (41.7)
Number of previous operations	None	19 (79.2)
	One	2 (8.3)
	Two	2 (8.3)
	Missing data	1 (4.2)

SD, standard deviation; TORP, total ossicular replacement prosthesis; PORP, partial ossicular replacement prosthesis.

Audiological Outcomes

Audiological data (BC, BC 4 kHz, AC, and ABG) were compared before and after ossiculoplasty. Details are shown in Table 2.

The analysis showed that there was a significant improvement in average AC threshold and in ABG ($P < .05$). For average BC threshold (and for BC at 4 kHz), no significant changes were observed. Before the operation, the majority of patients (75%) had an ABG of greater than 20 dB. Closure of the ABG to within 20 dB was observed after the operation in 67% of patients (Table 3).

Two-year Follow-up

Two-year follow-up data were available for 15 patients. The average BC threshold was $M = 16.83$ (standard deviation (SD) = 10.62) and BC at 4 kHz was $M = 28.67$ (SD = 16.74). The AC threshold was $M = 35.08$ (SD = 15.97), and the ABG was $M = 18.25$ (SD = 9.02). A successful hearing outcome 2 years after ossiculoplasty (≤20 dB ABG) was found in 73% of patients (11 out of 15).

Table 2. Comparison of Audiological Outcomes Before and After Ossiculoplasty

	Pre-op		Post-op		Test Result	*P*
	M	SD	M	SD		
BC threshold	20.00	10.15	17.92	11.07	1.54	.124
BC 4 kHz	33.54	19.02	30.83	17.61	1.08	.283
AC threshold	49.06	18.40	38.13	16.47	3.38	.001
ABG	29.06	11.88	20.21	7.98	3.06	.002

BC, bone conduction threshold (average of 0.5, 1, 2, and 4 kHz); AC, air conduction threshold (average of 0.5, 1, 2, and 4 kHz); ABG, air-bone gap; Pre-op, preoperative; Post-op, postoperative (i.e., 1 year after ossiculoplasty).

Table 3. Air-Bone Gap Before and After Ossiculoplasty

	ABG	n	%
Pre-op	≤10 dB	1	4.2
	10-20 dB	5	20.8
	20-30 dB	6	25.0
	30-40 dB	8	33.3
	40-50 dB	4	16.7
Post-op	≤10 dB	1	4.2
	10-20 dB	15	62.5
	20-30 dB	5	20.8
	30-40 dB	3	12.5

ABG, air-bone gap; Pre-op, preoperative; Post-op, postoperative.

Complications

One patient required revision surgery due to prosthesis extrusion. No other significant complications were observed.

DISCUSSION

The results of surgical treatment of posttraumatic ossicular chain disruption are generally good.[1,6,7] Yetiser[1] used several methods of reconstruction (fibrin glue, cement, incus interposition, different prostheses) and achieved a success rate of 72% (based on the closure of the ABG to within 20 dB). Shabana[6] achieved an 89% success rate in reconstructing damaged ossicles in 18 patients by using a teflon piston prosthesis, commonly used in stapes surgery, but in this case, it is placed on the mobile footplate. In this way, he could bypass the stapes superstructure, which was helpful in cases where it had fractured. Mundada[7] recommends performing fascial arthroplasty for displaced incus (reunion of the incudostapedial joint) if at all possible; using this method, he closed the ABG to within 10 dB in 80% of patients. In this study, we achieved a 67% success rate (16 out of 24) using titanium prostheses; the performance did not deteriorate with time in 11 of these 16 patients. However, note that these figures are based only on a small number of patients. Titanium ossiculoplasty is a well-recognized and generally successful method of treatment for hearing loss with a low rate of complications. According to the recent literature,[8-10] the extrusion rate ranges from 1.7% to 4.2%, in line with our study. Only 1 of our patients required revision due to prosthesis extrusion.

In cases of severe incus damage, a titanium prosthesis seems to offer a permanent solution. In recent publications on tympanoplasty with titanium prostheses, results from posttraumatic patients have not been distinguished from the general run of patients.[8-10] Vincent and colleagues[10] presented the results of 585 ossiculoplasties using hydroxyapatite, including 25 PORP and 10 TORP cases; overall, the success rate was 70.4% for PORP and 86.9% for TORP. In Wolter's pediatric material,[9] the use of a titanium TORP in a range of cases of damaged ossicular chain gave a 50% success rate; however, only 3 of these patients were operated on for posttraumatic reasons. Hess-Erga and colleagues[8] analyzed 44 PORP and 32 TORP ossiculoplasties and found good success rates (82% and 63%, respectively); of the reconstructions performed following trauma, success was achieved in 6 out of 6 cases. The results of our ossiculoplasties are similar to those of other authors. Note that, uniquely, our material focuses only on cases of posttraumatic lesion of the ossicular chain and the use of titanium prostheses.

In cases of posttraumatic hearing deterioration, the conductive loss may be due to blood in the tympanic cavity, perforation of the eardrum, or damage to the ossicles.[11] Blood clots usually resorb within weeks or months of injury; a similar period is required for spontaneous resolution of tympanic perforation, which is commonly encountered. These factors explain why surgical treatment should normally be delayed.[5] However, we are strong in the opinion that if there have been at least 6 months of persistent conductive hearing loss, then ossicular chain disruption should be suspected and surgery is then strongly recommended. Because the most common effects of trauma to the middle ear are incudostapedial disconnection or luxation of the incus, the natural solution is incus interposition.[12] Other materials such as fibrin glue, cement, or fragments of cartilage or bone can also be used to reconstruct damaged ossicles.[13]

Posttraumatic ossicular chain disruption can occur via 3 mechanisms. The most common is blunt head trauma, when a substantial force applied to the head leads to fracture of the temporal bone, and this usually originates from a traffic accident or substantial fall.[1] This type of injury was the most frequent in our material (8 cases), as it is also was in Yetiser's. Barotrauma is another cause of ossicular destruction, resulting from elevated pressure in the external ear canal due to a blow from the hand or a ball strike, but this is less common. There was a considerable range in the causes of trauma in our group of patients, one unusual and one being the schizophrenic patient who shot himself with an airgun.

CONCLUSIONS

Posttraumatic ossicular chain disruption is not common. It may be suspected when conductive or mixed hearing loss persists for several months, and during this time, the usual causes, such as a blood clot in the tympanic cavity or tympanic membrane perforation, tend to resolve spontaneously. We, therefore, believe that surgery should be delayed at least 6 months from the time of injury. Ossiculoplasty in such cases usually provides a satisfactory hearing outcome, and the use of a titanium prosthesis is a good option in cases of severe damage or absence of the incus.

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REFERENCES

1. Yetiser S, Hidir Y, Birkent H, Satar B, Durmaz A. Traumatic ossicular dislocations: etiology and management. *Am J Otolaryngol*. 2008;29(1):31-36. [CrossRef]

2. Basson OJ, van Lierop AC. Conductive hearing loss after head trauma: review of ossicular pathology, management and outcomes. *J Laryngol Otol*. 2009;123(2):177-181. [CrossRef]
3. Mills R, Starriit N. Management of incus dislocation by physiological repositioning of the incus. *J Laryngol Otol*. 2002;116(8):589-592. [CrossRef]
4. Delrue S, De Foer B, van Dinther J, et al., i in. Handling an isolated Malleus Handle fracture: current diagnostic work-up and treatment options. *Ann Otol Rhinol Laryngol*. 2015;124(3):244-249. [CrossRef]
5. Park GY, Choi JE, Cho YS. Traumatic ossicular disruption with isolated fracture of the stapes suprastructure: comparison with incudostapedial joint dislocation. *Acta Otolaryngol*. 2014;134(12):1225-1230. [CrossRef]
6. Shabana YK, Abu-Samra M, Ghonim MR. Stapes surgery for post-traumatic conductive hearing loss: how we do it. *Clin Otolaryngol*. 2009;34(1):64-66. [CrossRef]
7. Mundada PS, Dasgupta KS, Tapadiya GB. Temporalis fascia assisted ossicular arthroplasty for the dislocated incus: fascial arthroplastic ossiculoplasty. *Laryngoscope*. 2002;112(9):1699-1702. [CrossRef]
8. Hess-Erga J, Møller P, Vassbotn FS. Long-term hearing result using Kurz titanium ossicular implants. *Eur Arch Otorhinolaryngol*. 2013;270(6):1817-1821. [CrossRef]
9. Wolter NE, Holler T, Cushing SL, et al., i in. Pediatric ossiculoplasty with titanium total ossicular replacement prosthesis. *Laryngoscope*. 2015;125(3):740-745. [CrossRef]
10. Vincent R, Rovers M, Mistry N, Oates J, Sperling N, Grolman W. Ossiculoplasty in intact stapes and malleus patients: a comparison of PORPs Versus TORPs With malleus relocation and Silastic banding techniques. *Otol Neurotol*. 2011;32(4):616-625. [CrossRef]
11. Grant JR, Arganbright J, Friedland DR. Outcomes for conservative management of traumatic conductive hearing loss. *Otol Neurotol*. 2008;29(3):344-349. [CrossRef]
12. Wu KC, Shu MT, Yang CC. Autologous ossiculoplasty following temporal bone fracture. *J Laryngol Otol*. 2009;123(1):50-53. [CrossRef]
13. Nikolaidis V. Traumatic dislocation of the incudostapedial joint repaired with fibrin tissue adhesive. *Laryngoscope*. 2011;121(3):577-579. [CrossRef]