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ORIGINAL ARTICLE

# Conductive hearing loss after surgical treatment of otosclerosis – long-term observations

**Authors' Contribution:**
**A** – Study Design
**B** – Data Collection
**C** – Statistical Analysis
**D** – Data Interpretation
**E** – Manuscript Preparation
**F** – Literature Search
**G** – Funds Collection

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**ABSTRACT:**

**Introduction:** For many years, surgical treatment of otosclerosis has been a widely accepted approach. Hearing improvement following stapes surgery is sometimes spectacular, and good treatment results are obtained in many centers in over 90% of patients. However, in the subsequent years after the treatment, some patients develop permanent or progressive conductive hearing loss.

**Aim:** The aim of the study is to present a group of patients with conductive hearing loss after the first otosclerosis surgery and to analyze the causes of its occurrence.

**Materials and Methods:** The retrospective review covered patients who underwent the initial surgery in the years 2000–2009. We analyzed the patients' medical records from before the end of 2019, which provided results of at least 10 years of postoperative follow-up. The group consisted of 1118 patients aged 14–82, including 802 women and 316 men.

**Results:** Reoperations due to conductive hearing loss were performed on 93 patients, who accounted for 8.3% of the originally operated patients. They were much more common in patients after stapedectomies (19.7%) than in patients after stapedotomy (5.5%). Prosthesis dislocation was found to be the most frequent intraoperative observation (44.1%) and was often associated with erosion or necrosis of the long process of incus (28%). Less frequent reasons for hearing loss were: adhesions around the prosthesis (10.8%), too small hole in the stapes footplate (8.6%), too short prosthesis (8.6%), progression of otosclerosis (7.5%), too long prosthesis (6.4%), presence of a granuloma around the prosthesis (5.4 %), and displacement of incus (4.3%).

**Conclusions:** Surgical treatment of otosclerosis is a widely accepted and good method. It allows to achieve an improvement in hearing in the vast majority of patients treated in this way. Unfortunately, over the years some patients develop recurrent conductive hearing loss. Reoperation creates an opportunity for finding the cause and improving hearing in the majority of cases.

**KEYWORDS:** conductive hearing loss, otosclerosis, reoperation, restapedotomy, stapedectomy, stapedotomy

## INTRODUCTION

For many years, surgical treatment of otosclerosis has been a widely accepted approach, which consists in partial or total removal of the immobilized stapes and replacing it with a prosthesis made from metal or plastic. It initially began with complete removal of the immobilized and altered stapes, i.e., stapedectomy, and in the subsequent years, in line with the progress of medical technology, less invasive methods of surgery were employed. Hence, partial stapedectomy, also called partial posterior platinectomy, was introduced. The most widely accepted treatment is currently stapedotomy, which involves removing the stapes superstructure and creating a hole in the footplate [1, 2]. This hole can be created with the use of: micro--tools, micro-drills or a laser beam. The $CO_2$ laser provides an opportunity for creating a very precise hole with a diameter of 0.6–0.8 mm [3–7]. Similar to the surgical technique, there have been changes in the types of stapes prostheses used, which are made of different types of bio-neutral materials and in various shapes [1, 2, 8, 9].

Hearing improvement following stapes surgery is sometimes striking, and good treatment results are obtained in many centers in over 90% of patients [1, 10–12]. However, in the subsequent years after the treatment, some patients develop permanent or progressive conductive hearing loss. It is estimated that as many as 10–20% of patients can expect such a scenario, which shall require a decision on the next microsurgical intervention. Literature reports also show that the therapeutic success after reoperation in otosclerosis is observed less frequently compared to the initial otosclerosis surgery and ranges between 24 and 80% [1, 13–18].

The aim of this study is to present a group of patients with conductive hearing loss that appeared after the initial otosclerosis surgery and to analyze the reasons for its occurrence.

## MATERIALS AND METHODS

There were 3,171 patients treated surgically for otosclerosis at the Department of Otolaryngology and Laryngological Oncology of the

**Tab. I.** Table summarizing the causes of hearing loss, determined intraoperatively.

| | | |
|---|---|---|
| 1. | Prosthesis dislocation<br>· partial destruction (erosion) of the long process of incus,<br>· total necrosis of the long process of incus,<br>· prosthesis dislocated, incus correct. | 41 (44.1%)<br>17<br>9<br>15 |
| 2. | Adhesions around prosthesis | 10 (10.8%) |
| 3. | Too small hole in footplate | 8 (8.6%) |
| 4. | Too short prosthesis | 8 (8.6%) |
| 5. | Progression of otosclerosis | 7 (7.5%) |
| 6. | Too long prosthesis | 6 (6.4%) |
| 7. | Granuloma around prosthesis | 5 (5.4%) |
| 8. | Dislocated incus | 4 (4.3%) |
| 9. | Other, unclear | 4 (4.3%) |

**Fig. 1.** Reoperation of the left ear – the stapes prosthesis has been found to slip off the long process of incus

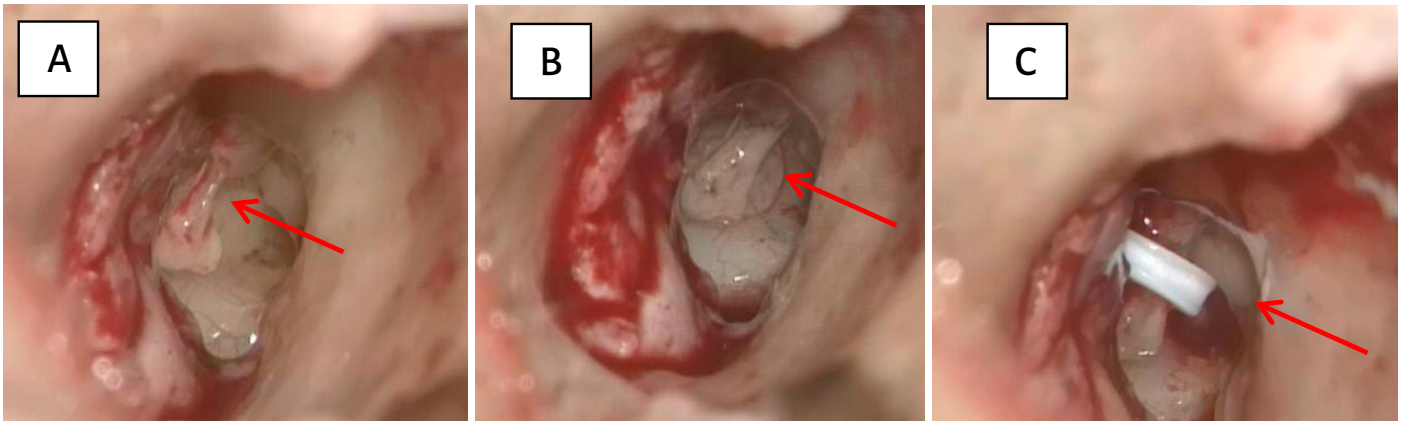


**Fig. 2.** Reoperation of the left ear – after opening the tympanic cavity and removing the loose prosthesis, erosion of the long process of incus was found (A); the thin section of the long process of incus was reconstructed with biocement (B) and a new stapes prosthesis was placed (C).

Poznań University of Medical Sciences in the years 1984–2019. The retrospective review covered patients who underwent the initial surgery in the years 2000–2009. We analyzed the patients' medical records from before the end of 2019, which provided results of at least 10 years of postoperative follow-up. The group comprised 1,118 patients aged 14–82 years, including 802 women (71.7%) and 316 men (28.3%). The patients had undergone the following surgeries:

- stapedotomy – 895 cases (80%),
- partial stapedectomy – 161 cases (14.4%),
- stapedectomy – 62 cases (5.6%).

During stapedotomy, the hole in the stapes footplate was created with a: microneedle (351 cases), micro-drill (41 cases), a $CO_2$ laser or the Er-Yag laser (503 cases). In 1070 patients (95.7%), the treatments were carried out under local anesthesia and NLA, while in 48 (4.3%) under general anesthesia (children and uncooperative adults).

## RESULTS

In the analyzed group of 1118 patients operated in the years 2000–2009 in the follow-up period till the end of 2019, 93 (8.3%) underwent reoperation due to conductive hearing loss, including 69 women and 24 men. The age of the patients was from 24 to 64 years, with a mean age of 41. Reoperations following stapedotomy were performed in 49 patients, and following stapedectomy in 44 (38 partial and 6 total). The time from the initial surgery to reoperation varied. Patients who reported no hearing improvement during the first visit (7–8 weeks) were reoperated after 6 months (24 patients), while for the remaining 69 patients the time varied between 1 year and 8 years, with a mean of 4.5 years.

All operations were performed through an intra-meatal approach with incision of the skin and soft tissues of the external auditory canal at 12 and 6 o'clock. After the tympanic cavity was opened, the surgical site was visualized and meticulously examined to determine the cause of hearing loss. In each case, the stapes prosthesis was removed and replaced with a new one almost always at the same time (an exception was the presence of a granuloma, where placement of the prosthesis was postponed for several months). The instruments used were micro-tools and a $CO_2$ laser beam.

It should be noted that all manipulations were more difficult than in the initial operation due to scarring and adhesions in the tympanic cavity. Intraoperative findings are presented in Tab. I.

**Tab. II.** Summary of reasons for hearing loss depending on the types of operations.

| | TYPES OF OPERATIONS | |
|---|---|---|
| | Stapedotomy (49) | Stapedectomies (44) |
| Prosthesis dislocation | 17 | 24 |
| Adhesions around prosthesis | 6 | 4 |
| Too small hole in footplate | 8 | 0 |
| Too short prosthesis | 4 | 4 |
| Progression of otosclerosis | 5 | 2 |
| Too long prosthesis | 3 | 3 |
| Granuloma around prosthesis | 3 | 2 |
| Dislocated incus | 2 | 2 |
| Other, unclear | 1 | 3 |

**Tab. III.** Summary of causes depending on the time that has elapsed since the initial operation.

| CAUSES OF HEARING LOSS | HEARING LOSS REPORTED AFTER REMOVAL OF DRESSING (DAY 10) AND IN THE FIRST 3 MONTHS – 24 | SUBSEQUENT HEARING LOSS – 69 |
|---|---|---|
| Prosthesis dislocation | 6 | 35 |
| Adhesions around prosthesis | 1 | 9 |
| Too small hole in footplate | 5 | 3 |
| Too short prosthesis | 5 | 3 |
| Progression of otosclerosis | 0 | 7 |
| Too long prosthesis | 4 | 2 |
| Granuloma around prosthesis | 1 | 4 |
| Dislocated incus | 2 | 2 |
| Other, unclear | 0 | 4 |

For almost half of the cases (41/93), it was established that the cause for hearing loss was dislocation of the prosthesis, including the tip, which was not located in the hole in the footplate or in the oval window, and often rested against the bony edge of the oval window niche. In this group we observed the largest number of cases (17/41) of partial destruction (erosion) of the long process of incus, and less frequently (9/41) a fragment of the long process showed complete necrosis, which led to a significant dislocation of the prosthesis. In 15/41 cases, a prosthesis was found loosely stacked in the tympanic cavity with a completely preserved long process of incus (Fig. 1.). In 9 cases, the mechanism of dislocation was explained successfully. Specifically, in 3 cases the patients reported a relationship between hearing loss and a traffic accident and hitting the head on the car window or the dashboard; in 2 cases, the hearing deteriorated after falling off a horse; in 1 case after a bicycle ride and a crash into a tree. In 3 cases, the long process of incus was thinner than normal and was not pressed properly by the prosthetic head. In the case of partial destruction (erosion) or complete necrosis of the long process of incus, it was strengthened or reconstructed with biocement, followed by restoration of the hole in the footplate and placement of a new prosthesis, usually in a slightly different location (closer to the body of the incus) (Fig. 2.). In the remaining cases, the hole in the footplate was restored and a new prosthesis was placed in a conventional manner.

Adhesions near the prosthesis and oval window were the second most common cause of hearing loss after surgery of otosclerosis. They were found in 10 reoperated patients (10.8%) and were most likely the consequence of bleeding during the initial surgery. After the adhesions were removed with a delicate needle and microscissors or a $CO_2$ laser, the old prosthesis was removed and replaced with a new one.

In turn, in 8 cases (8.6%) we estimated that the cause of the hearing loss could be the insufficient size of the hole in the footplate. In 6 patients, during the initial operation we found that the facial nerve was anteplaced and obstructed more than half of the footplate, and hindered creating an appropriate hole. During reoperation, the prosthesis was removed, the hole was expanded slowly and gradually under control of facial nerve monitoring, and a new, thinner prosthesis was placed. In the remaining 2 cases, the hole was expanded, obtaining good mobility of the prosthesis.

In 8 patients (8.6%) the prosthesis was too short, which in 3 cases led to closure of the footplate, and in the remaining cases (after partial stapedectomy) to sound conduction disorders (Fig. 3.). The new prosthesis was refitted, which solved the problem.

During reoperation, 7 patients (7.5%) were found with progression of otosclerosis with immobilization of the prosthesis. Removing the prosthesis and expanding the overgrown hole in the footplate gave good results. It should be noted that 2 women from this group used hormone therapy for 6–8 years after the initial surgery.

In another 6 patients (6.4%) the prosthesis was too long, which led to dizziness. This ailment appeared shortly after the operation. The prosthesis was exchanged for a slightly shorter one which resulted in resolution of symptoms.

Five patients (5.4%) were diagnosed with a granuloma around the prosthesis, which was probably a reaction to the foreign body, i.e. the prosthesis. Each time the prosthesis was removed, if it was possible the granuloma was removed with it. In 4 cases, the tympanic cavity was reopened after 6–8 months, and it was found that the granuloma had receded, which enabled the placement of a new prosthesis.

In 4 cases (4.3%), luxation of the incus was found, which probably occurred during placement of the prosthesis or removal of bone overhang during the initial operation. It is a difficult operational situation, which requires complete or partial removal of the incus and performance of malleostapedotomy.

The last group of 4 patients (4.3%) represents unclear cases, in which the cause of the hearing loss could not be established and replacement of the prosthesis did not improve hearing considerably.

It has to be recognized that conductive hearing loss after surgery was much more common in patients after stapedectomy (44/223, i.e., 19.7%) than in patients after stapedotomy (49/895, i.e., 5.5%). Detailed particulars of causes for conductive hearing loss depending on the type of surgery performed are presented in Tab. II.

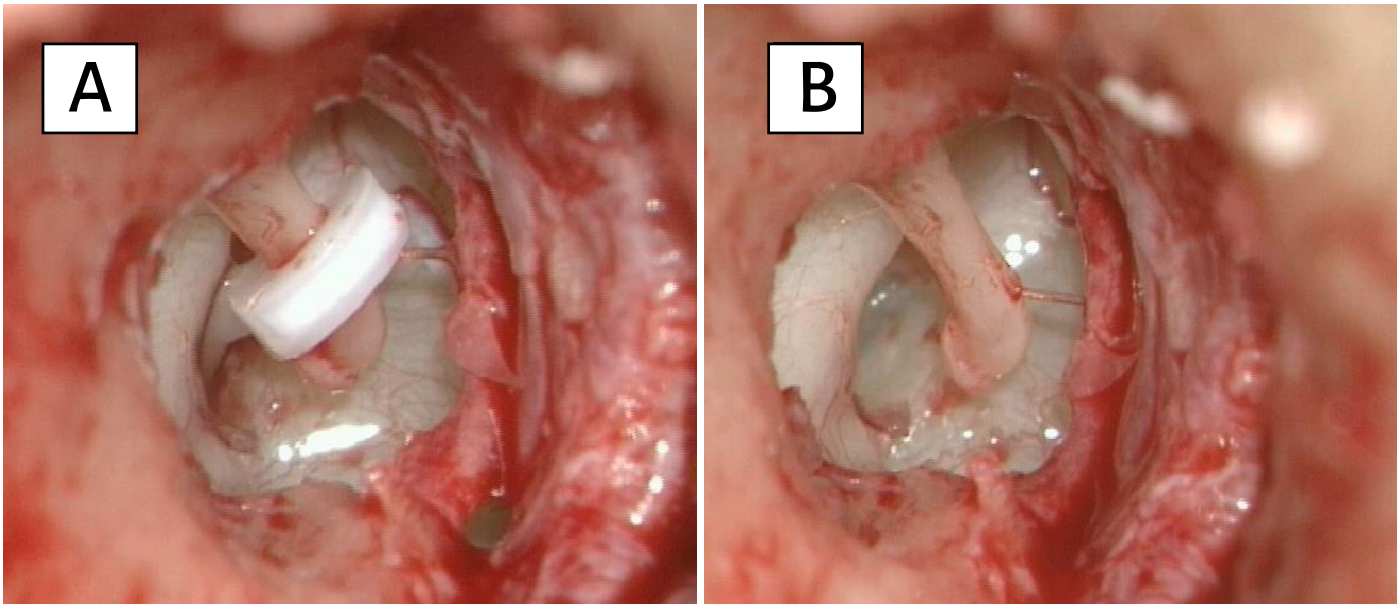


**Fig. 3.** Reoperation of the right ear – the tympanic cavity was opened and a correctly positioned stapes prosthesis and an anteplaced facial nerve were exposed (A); removal of the stapes prosthesis revealed a completely overgrown stapes footplate (B).

Tab. III. summarizes the causes of hearing loss depending on the time elapsed after the initial surgery. Most of the prosthesis dislocations occurred 3–4 years after the procedure. Similarly, the progression of otosclerosis and the presence of adhesions were usually observed many years after surgery.

## DISCUSSION

Conductive hearing loss after surgical treatment of otosclerosis occurred in 8.3% of patients at our center in over 10 years' follow-up. Such data are also presented by other authors [1, 13–15, 18–20]. The results of our analysis suggest that in the majority of such patients there is a possibility of surgical improvement of hearing. According to the literature, restapedotomy creates an opportunity for improving hearing in 24–80% of cases. The outcomes depend on the type of previously performed procedure, the model of the prosthesis and the cause of recurrent hearing loss [1, 16, 18]. Improving results over the years are also associated with the possibility of applying laser techniques for revision surgery [2, 14]. In our study, hearing could not be restored in merely 4 out of 93 cases, in which the reason for the failure was not identified.

Final auditory results after surgical treatment of otosclerosis should be assessed not earlier than after 3–6 months, whereby some authors even encourage extending this period up to 12 months [19]. It therefore seems that the decision on restapedotomy, with the exception of urgent cases, should be postponed until then. Before that, it is recommended to attempt conservative treatment or clinical observation (wait and see policy) [1]. Most of the analyzed patients were reoperated at least one year after the initial intervention. In 24 cases, such a procedure was undertaken somewhat faster but not earlier than 6 months after the initial treatment. Those were patients in whom:

- no improvement in hearing was observed after removal of the intra-aural dressing,
- hearing deteriorated in the early postoperative period,
- accompanying symptoms (dizziness) or circumstances (head injury) suggested the etiology for the recurrence of hearing loss (too long prosthesis, prosthesis dislocation).

The most frequent causes of conductive hearing loss after surgical treatment of otosclerosis described in world literature are prosthesis dislocation [13, 14, 21–23]. The same applies to our study (44.1% of patients). Prosthesis dislocation often entails erosion or necrosis of the long process of incus. This occurs mostly in the mechanism of ischemia due to compression of the incus artery by the prosthesis. Damage to the long process of incus was found in 28% of the reoperated patients. In all cases of erosion or necrosis, it was strengthened or restored with biocement, and the new prosthesis was usually placed in a somewhat different location. In the case of conductive hearing loss related to prosthetic dislocation, it is recommended to use a new prosthesis rather than relocate the one used during the previous procedure. This was the standard practice for all our patients.

In 43 reoperated cases, McGee recognized the presence of the so-called "loose wire syndrome", previously described by Schuknecht and included in the group of causes of hearing loss after stapedotomy related to prosthesis dislocation [21]. McGee observed a periodic improvement in hearing with a change of middle ear pressure in operated patients, and intraoperatively found partial destruction of the long process of incus due to demineralization. In 2002, Lesiński reported that the syndrome involves lifting of the prosthesis and partial destruction of the incus. In his group of patients the symptoms occurred when the end of the prosthesis touched the bony rim of the hole in the footplate or the oval window, which immobilized it. The constantly vibrating long process of incus then hit the head of prosthesis, which led to partial necrosis of

the incus bone tissue [22]. In 2009, Lagleyere et al. described this phenomenon and called it the "lateralized piston syndrome" [23]. It seems that this mechanism could be attributed to some cases of incus necrosis found in our study during reoperation.

The next most common cause of conductive hearing loss after surgical treatment of otosclerosis is the formation of adhesions in the tympanic cavity. According to the literature, it concerns from 2 to 37.5% of cases. Pathomechanisms take into account the increased local inflammatory process related to a reaction to a foreign body, such as a prosthesis or granulation caused by increased intraoperative bleeding or iatrogenic injury to the mucous membrane of the tympanic cavity [1, 14]. Adhesions usually form around the prosthesis and the oval window. In our study, they were the cause of hearing loss in 10.8% of the reoperated patients. In the majority of cases, adhesions concerned patients who had profound intraoperative bleeding during the initial operation.

One of the more difficult surgical situations that can be encountered during revision surgery after stapedotomy/stapedectomy is the case of a luxated incus. The authors almost unanimously emphasize the superiority of malleostapedotomy over other ossiculoplasties in such a situation, including the use of a TORP prosthesis [24]. The auditory results after employing the former are significantly better. In our study, a luxated incus was found in 4 reoperated patients. Malleostapedotomy was successfully used in all of them.

When deciding on reoperation after stapedotomy/stapedectomy, it should also be noted that it is usually a more difficult procedure than the initial operation. It follows from a fact that usually there is a need to dissect adhesions in the tympanic cavity, as well as problems with the atraumatic removal of the previously used prosthesis. Furthermore, it is associated with a higher risk of complications than in the initial procedure, including hearing loss and injury to the facial nerve.

The recommendation for reoperations is to use laser techniques, whose superiority has been documented especially in cases of intense adhesions in the vicinity of the oval window, preventing its precise location [13]. Reoperation of patients at our center involved the repeated use of the CO2 laser in such situations.

## CONCLUSIONS

Surgical treatment of otosclerosis is a widely accepted and good method. It allows for achieving an improvement in hearing in the vast majority of patients treated in this way. Unfortunately, over the years some patients experience recurrent conductive hearing loss. In our study, recurrent hearing loss was found in 8.3% of patients at 10 years' follow-up, much more frequently after stapedectomy (19.7%) than after stapedotomy (5.5%). Most of the time it resulted from the dislocation of the prosthesis (44.1%). Reoperation gives a chance to improve hearing in most of these cases. Except in urgent cases, the decision to perform revision surgery should be made after at least a 6-month follow-up period from the initial treatment. It is recommended to use laser techniques in reoperations.

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