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# Endoscopic ossiculoplasty in traumatic conductive hearing loss with intact tympanic membrane: a five-year experience

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## Main Article

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## Abstract

**Background.** Exploratory tympanotomy in cases of traumatic ossicular disruption with intact tympanic membrane is crucial for both diagnostic and therapeutic purposes. Performing this procedure using the endoscope is gaining popularity. Hence, this study aimed to demonstrate varieties of ossicular pathology and their management in our institution.

**Methods.** A retrospective evaluation was conducted of 136 ears in patients with traumatic ossicular disruption with an intact tympanic membrane, who underwent endoscopic exploratory tympanotomy. A proposed algorithm was followed, to incorporate different traumatic ossicular possibilities. Assessment of hearing outcomes and surgical complications was performed six months post-operatively.

**Results.** Incudostapedial dislocation was the most commonly encountered type of traumatic ossicular disruption (35.3 per cent). Air conduction threshold improved significantly following endoscopic ossiculoplasty, from 50.9 ± 6.35 dB pre-operatively to 22.35 ± 3.27 dB post-operatively, with successful air–bone gap closure.

**Conclusion.** Endoscopic ear surgery is effective in the diagnosis and management of challenging cases of post-traumatic ossicular disruption with an intact tympanic membrane.

## Introduction

Traumatic ossicular injury is a frequently encountered problem after head trauma. It has various causes, including motor car accidents or falling from a height, resulting in disruption of ossicular chain continuity.[1] It usually presents as conductive hearing loss with an average range of 20–60 dB.[2,3] When this conductive hearing loss presents in patients with an intact tympanic membrane, it becomes more challenging to detect the exact ossicular pathology and to prepare a certain management plan for reconstruction of the ossicular chain (ossiculoplasty).[4]

Advancement in radiological techniques has allowed for excellent pre-operative prediction of the ossicular problem. However, exploratory tympanotomy remains the standard approach for both establishment of the clinical diagnosis and management of the lesion.[5] Transcanal endoscopic ear surgery offers an excellent view of the ossicles and allows for successful repair in almost all cases, with proven success.[6–9]

The main surgical concern in these cases is the different possible pathological findings according to the trauma experienced. Subsequently, the corrective operative technique should be tailored to each specific case.[10–15] This malleability in intra-operative decision-making can be facilitated by collectively determining the possible ossicular findings and their appropriate corrective procedure.

The current study presents our simplified approach and endoscopic experience for reconstruction of the ossicular chain following traumatic ossicular injury, in patients with an intact tympanic membrane presenting at our tertiary care centre.

## Materials and methods

### *Study design and patient characteristics*

All adult cases with traumatic ossicular disruption who presented to our tertiary referral centre over a five-year period were retrospectively evaluated. The patients included in the study had conductive hearing loss with an intact tympanic membrane. All cases were managed with exclusive transcanal endoscopic ear surgery. In patients with concomitant facial nerve injury, only those who had solely endoscopic management were included. Cases that necessitated mastoidectomy for decompression or management of other associated injuries were excluded. In addition, patients with a history of middle-ear surgery or with a follow-up period of less than six months were not included. This study was

approved by our ethical committee and a written consent was obtained from the patients studied.

### Pre-operative evaluation

Demographic data, operative findings, and pre- and post-operative audiograms were reviewed. Pure tone averages for each patient were determined by averaging hearing thresholds at 0.5, 1, 2 and 3 kHz; the air–bone gap was defined as the difference between air and bone conduction levels.[16]

All computed tomography (CT) scans were performed after the initial trauma in the period between three weeks and one year using the Ingenia CT system (Philips Healthcare, Amsterdam, the Netherlands). Any remaining haemotympanum was allowed to resolve during this three-week period, to allow better studies. The images were obtained with the following parameters: 0.67 mm slice thickness, 0.5 second rotation time, 0.5–1 pitch factor, 140 KV tube voltage, 160 mA tube current, 200 mm scan field of view, 725 × 725 matrix, window level = 600 HU and window width = 4000 HU. The images were then reconstructed with 0.3 mm slice thickness. Images were exported to the Synapse picture archiving and communication system (Fujifilm, Tokyo, Japan). The CT images underwent multi-planner reformatting and three-dimensional (3D) volume rendering, and findings were interpreted by a senior consultant radiologist. A luxation or subluxation of the incudomalleolar or incudostapedial joint was defined as the presence of a gap or lack of osseous continuity between the ossicles on 3D reconstruction.

### Surgical technique

All surgical procedures were conducted under local anaesthesia. The standard procedure was an endoscopic transcanal exploratory tympanotomy, namely a transcanal endoscopic ear surgery class 3, as described by Cohen, Lee and colleagues.[17] The instruments utilised included 0° and 30° rigid endoscopes (outer diameter of 4 mm and length of 18 cm) (Karl Storz, Tuttlingen, Germany) connected to a high-definition camera and monitor. The light source power was adjusted to 60 per cent, to guard against possible thermal side effects. The standard instruments for transcanal endoscopic ear surgery were used.

The exploration procedure usually starts by infiltration of the post-auricular skin and ear canal with a local anaesthetic solution containing diluted adrenaline. A standard posterior canal wall incision was then made, between the 12- and 6-o'clock positions. Then, a round knife was used to elevate a posterior tympanomeatal flap. In order to facilitate haemostasis

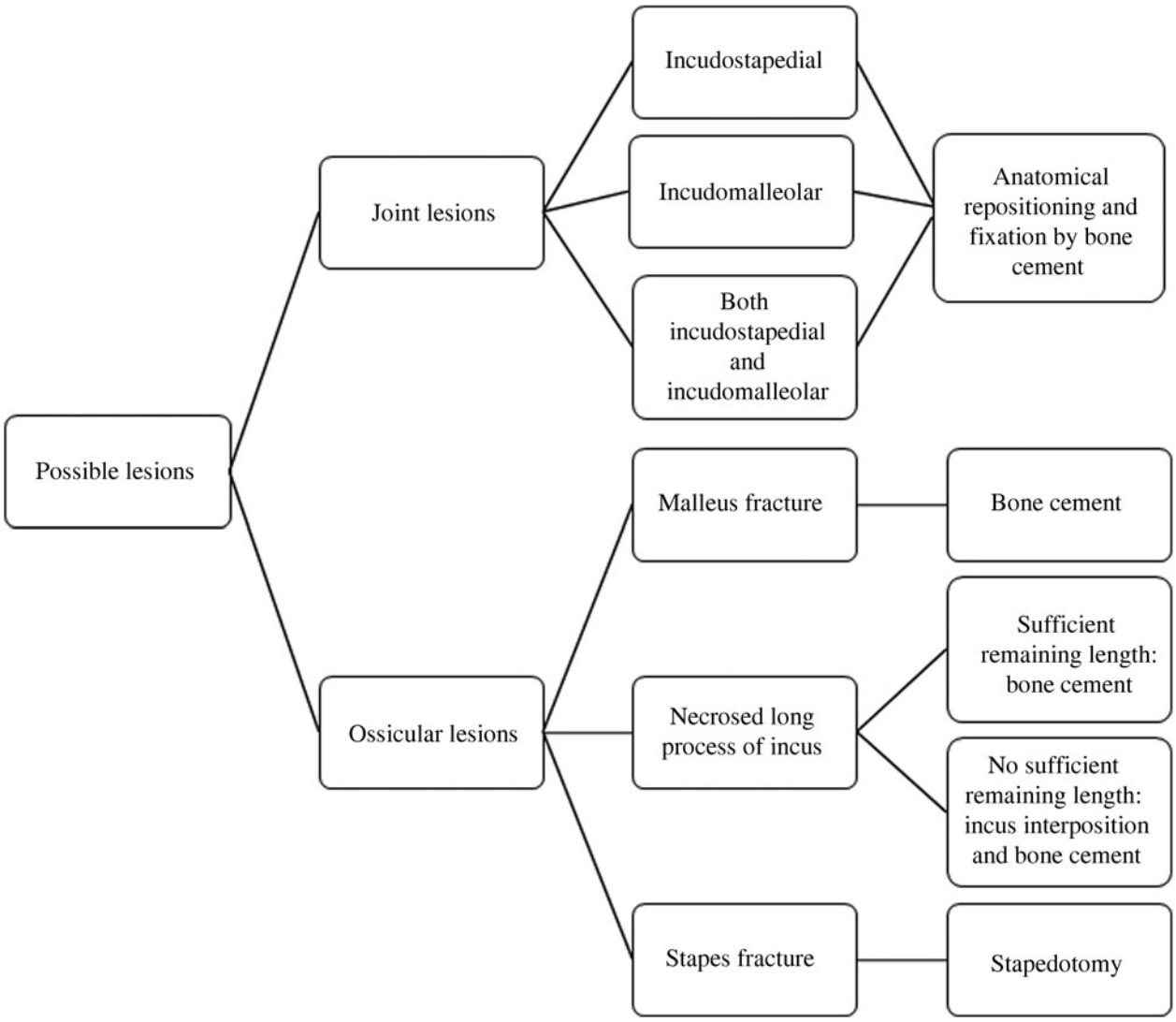


**Figure 1.** Algorithm for management of various possibilities of traumatic ossicular injury in patients with an intact tympanic membrane.

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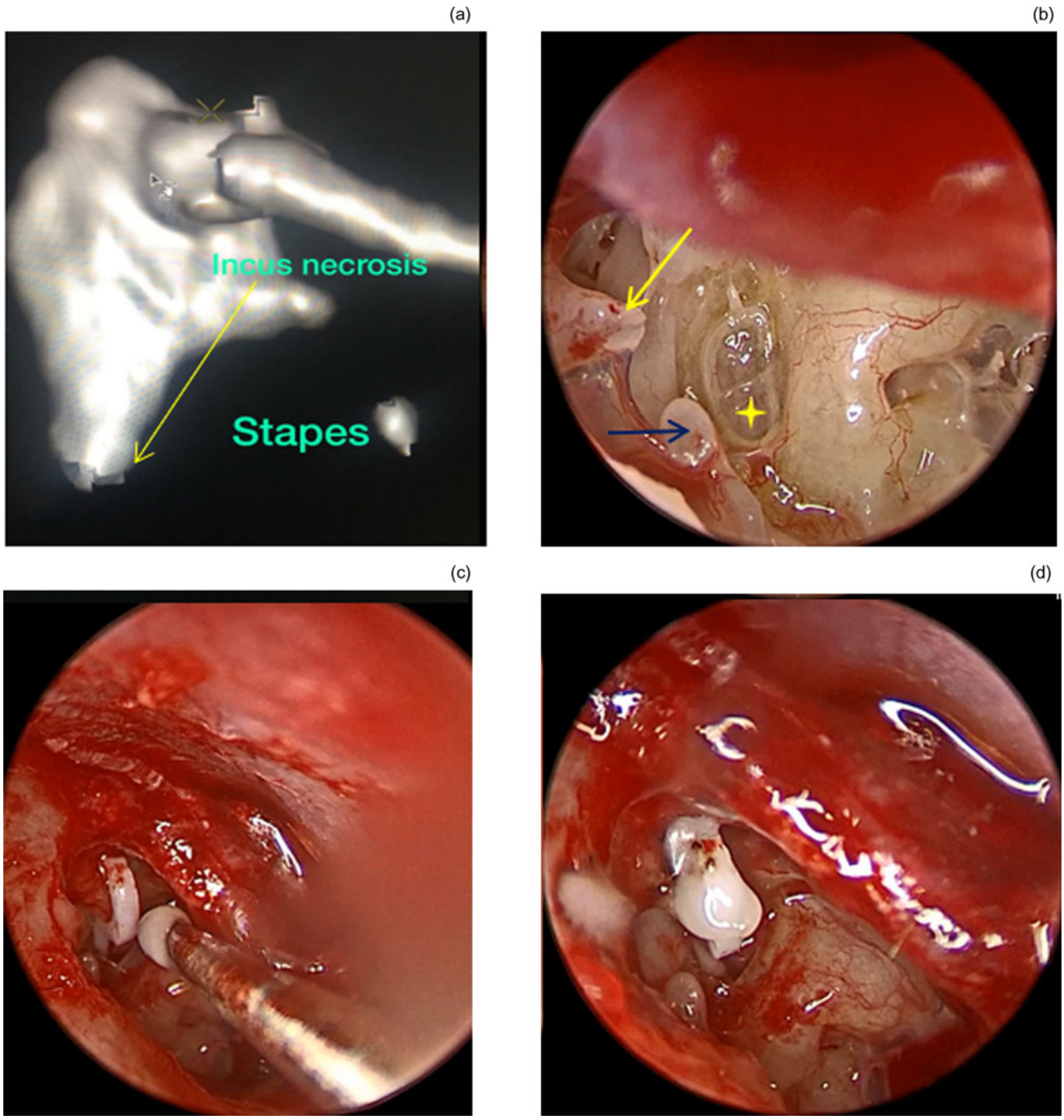


**Figure 2.** Pre-operative three-dimensional (3D) computed tomography (CT) scan, intra-operative findings and view of ossiculoplasty performed for traumatic conductive hearing loss in a right ear. (a) Pre-operative 3D CT scan shows necrosis of the long process of the incus (yellow arrow) with separation from the head of the stapes. (b) Endoscopic view of the middle ear after tympanomeatal flap elevation showing a necrosed long process of the incus (yellow arrow) separated from the head of the stapes (blue arrow). Note that the head of the stapes is retracted posteriorly from the footplate (yellow star) with absent crura. (c) Endoscopic view shows a piston Teflon prosthesis inserted through stapedotomy hole and attached to the remaining part of the long process of the incus. The tip of the instrument shows bone cement before its application on the head of the prosthesis. (d) Endoscopic picture after establishing ossicular connection between the necrosed long process of incus and the Teflon piston via bone cement.

throughout the procedure, topical 1:100 000 adrenaline-soaked cottonoids were used. After identification and dissection of the chorda tympani nerve, the ossicular chain was inspected and palpated to confirm the traumatic pathology.

The algorithm presented in Figure 1 was followed to address the different traumatic ossicular possibilities. Some of the frequently encountered pathologies and their methods of management are demonstrated in Figures 2–4. The bone cement used in these cases was Gold Label glass ionomer luting and lining bone cement (GC, Tokyo, Japan).

Additional endoscopic facial decompression of the tympanic segment was carried out for the patients suffering from associated complete facial palsy. These patients presented with facial nerve paralysis immediately after the trauma, with radiological suspicion of a compromised tympanic segment, by a dislocated ossicle or bony spicule.

### *Post-operative evaluation and follow up*

Post-operative audiometric evaluation was conducted six months post-operatively. Successful treatment was defined as a post-operative air–bone gap of less than 20 dB.[18] Possible complications such as hearing loss, tympanic membrane perforation and taste affection were recorded.

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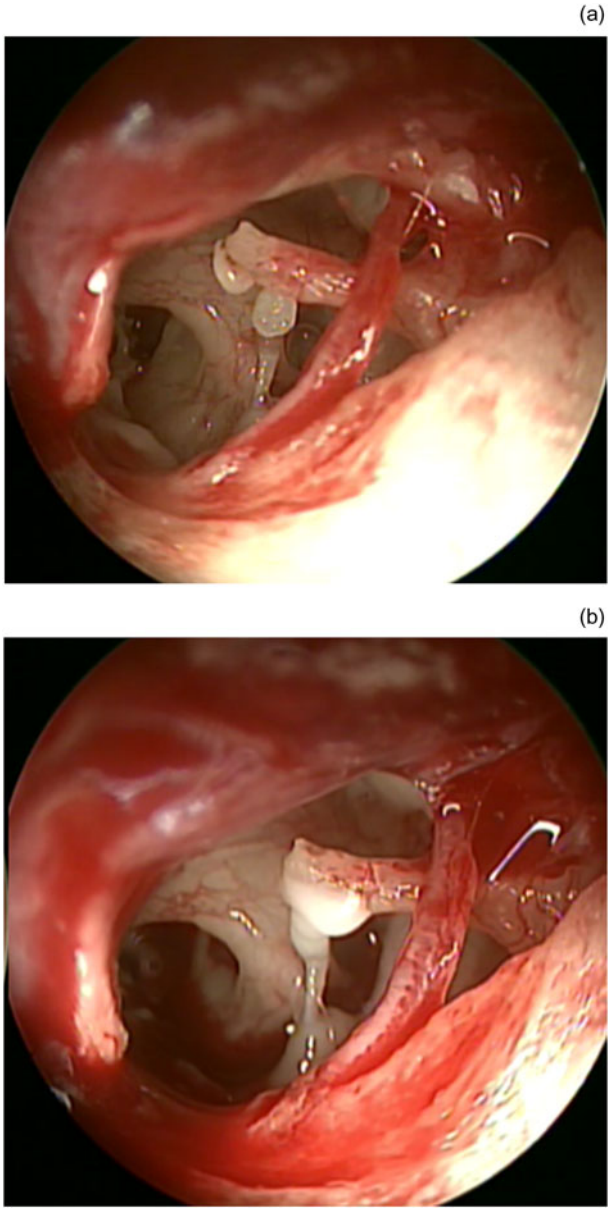


**Figure 3.** (a) Endoscopic view of the left middle ear after tympanomeatal flap elevation showing incudostapedial joint dislocation. (b) Endoscopic view after relocation of the long process of the incus to its normal position over the head of stapes, with stabilisation of the joint by bone cement.

### *Statistical analysis*

Statistical analyses were performed using SPSS software version 18.0 (SPSS, Chicago, Illinois, USA). The Mann–Whitney U test and one-way analysis of variance were used to compare the variables between two or more groups. Results are presented as means ± standard deviation. A *p*-value of less than 0.05 was considered statistically significant.

## Results

A total of 136 ears were retrospectively analysed. The patients, aged 18–50 years, underwent transcanal endoscopic ossiculoplasty for post-traumatic conductive hearing loss. A summary of patients' demographic and clinical characteristics are demonstrated in Table 1. Motor car accidents were the most common aetiology of trauma (52 cases) followed by falling from a height (36 cases).

Improvement of the average air–bone gap was achieved, increasing from 33.6 ± 4.61 dB pre-operatively to 3.2 ± 1.85 dB post-operatively. The air–bone gap closure was within 10 dB in all cases. While the bone conduction threshold did not show a significant difference between the pre- and post-operative values, the air conduction threshold improved significantly, from 50.9 ± 6.35 dB pre-operatively to 22.35 ± 3.27 dB post-operatively ($p < 0.001$).

The most frequently encountered disruption was incudostapedial dislocation (35.3 per cent). It was managed in all included cases by repositioning the dislocated joint, followed by bone cement augmentation. Ossiculoplasty using bone cement only was conducted in eight cases to treat a fractured malleus or necrosed long process of incus, with sufficient length remaining. Forty-four cases were found to have incus luxation, making it the second most frequently encountered pathology. In the 36 cases of isolated incus laxation, the incus was repositioned in its anatomical position and stabilised with bone cement. In the eight cases associated with stapediovestibular dissociation or stapes fracture, additional stapedotomy was carried out using a Teflon piston prosthesis. Stapedotomy per se was indicated when an isolated stapes suprastructure fracture was found, or in presence of stapediovestibular with incudostapedial dislocation (Table 2). In all cases, detailed analysis of the state of the ossicular chain by the surgeon confirmed the 3D CT analysis of the senior radiologist, with 100 per cent sensitivity.

Normal facial nerve function was regained after surgery in all patients with pre-operative facial nerve paralysis. No new-onset post-operative facial paralysis was detected. In addition, there were no reports of sensorineural hearing loss, and none of the surgical procedures were converted to an open approach. Apart from transection of the chorda tympani nerve in one case, no other major complications were observed. In the case of chorda tympani nerve transection, there were tight adhesions between it and the dislocated incus, with excessive fibrous tissues surrounding it.

## Discussion

Traumatic ossicular injury continues to be a challenging point of discussion among otologists. Microscopic ossiculoplasty was the traditional approach for treatment of these cases.[4,19,20] In recent years, transcanal endoscopic ear surgery has demonstrated obvious advantages, such as good illumination and a wide multi-angled view, which are extremely beneficial in the accurate assessment of ossicular disruption and simultaneous ossiculoplasty.[12,21,22] An increasing number of reports discussing the role of transcanal endoscopic ear surgery have been published that confirm this endoscopic efficacy.[8,15,23]

Regardless of the instrument used, there are different methods for ossicular reconstruction, involving autologous materials, bone cement and synthetic prostheses.[6] Advocates of autologous materials report that these materials are more naturally and anatomically accepted, although they require additional expertise and surgical time. In contrast, prosthetics are readily available in a variety of shapes, materials and sizes, but with associated risks such as extrusion and infection.[24] Although there are no recommendations denoting the superiority of either material type, autologous bony ossicles and bone cement are more commonly implemented in patients with an intact tympanic membrane because of the low or rare possibility of complete loss of ossicles. Hence, the authors in the present study preferred restoring the natural

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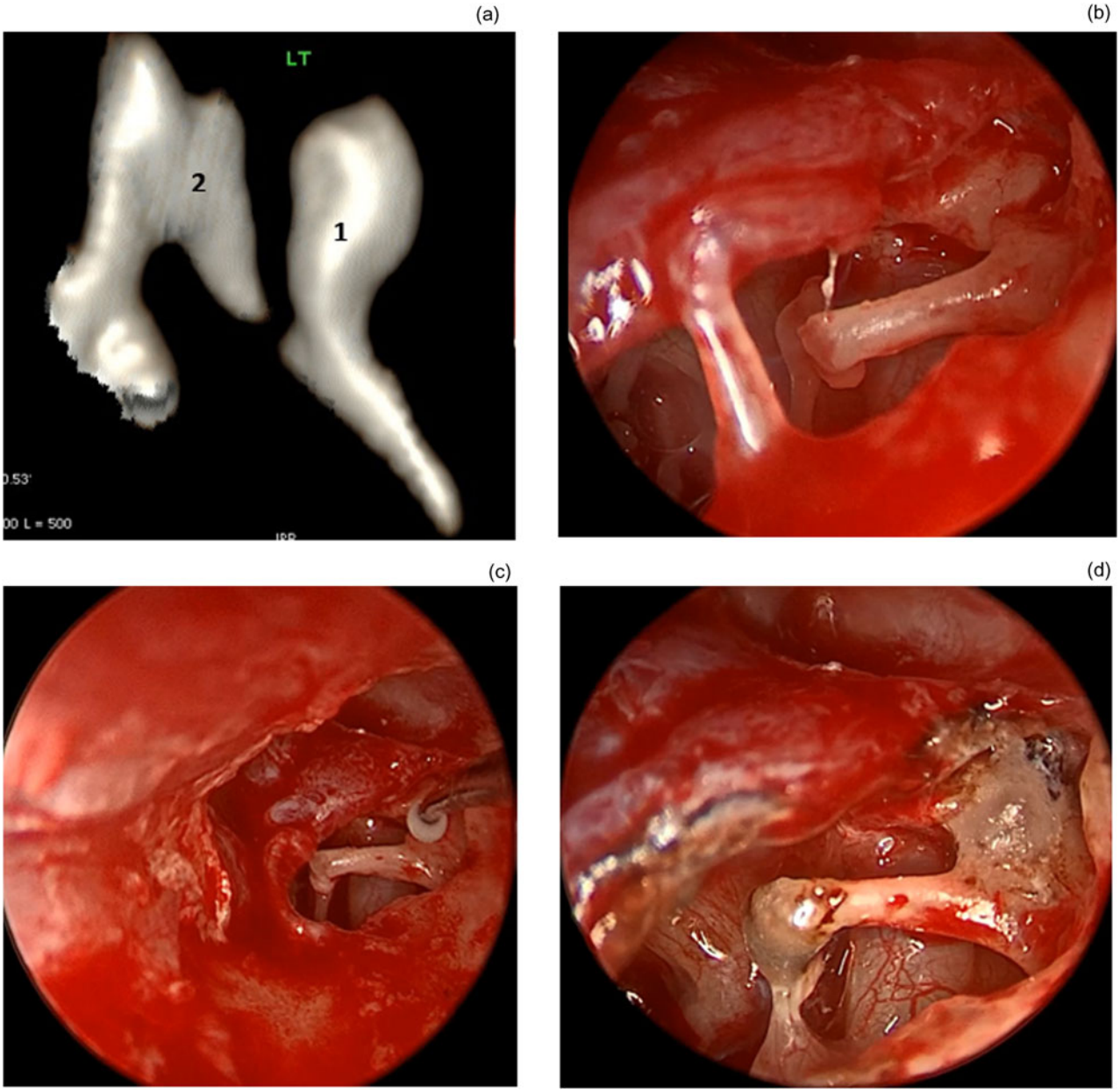


**Figure 4.** Pre-operative three-dimensional (3D) computed tomography (CT) scan, intra-operative findings and view of ossiculoplasty performed for traumatic conductive hearing loss in a left ear. (a) Pre-operative 3D CT scan shows incus luxation, with a gap between the malleus (1) and the incus (2), and between the incus (2) and the stapes, suggesting incudomalleolar and incudostapedial dislocation. (b) Endoscopic view of the middle ear after tympanomeatal flap elevation, showing incudomalleolar and incudostapedial dislocation. (c) Endoscopic view after repositioning of the incus to its normal position. The tip of the instrument shows bone cement before application. (d) Result after stabilisation of the incudomalleolar and incudostapedial joints by bone cement.

anatomical continuity between ossicles, using repositioning and bone cement whenever possible. The use of a prosthesis was limited to cases that cannot be repaired in this natural way, as in stapes fracture cases where a Teflon piston was used. Tailored reconstruction of ossicular chain continuity was performed according to the specific pathology in the least synthetic and most naturally accepted way. This paper does not focus on proving the superiority of a certain technique, but rather focuses on presenting our approach.

The most frequently encountered pathology in our patients was related to incus dislocation, and separation from either incudomalleolar or incudostapedial joints or both. This finding is supported by previous studies and is explained by the weak suspensory support of the incus between the firmly anchored malleus and the stapes.[2,19,25] Isolated fractures of the malleus handle and long process of the incus were rarely reported.[19,26,27] In addition, a stapes suprastructure fracture is frequently associated with direct penetrating ear trauma;[28] this explains the paucity of such cases in the current study.

The most common causative aetiology for traumatic ossicular injury is head trauma, either resulting from a traffic accident or falling from a height. This finding is consistent with previous reports.[4,25] These injuries are usually accompanied by temporal bone fractures, a perilymphatic fistula or a facial nerve injury.[2] These associated issues can be considered a limitation to the exclusive transcanal endoscopic ear surgery, as an additional approach may be needed for successful management of these cases. No perilymphatic fistulae were observed in our cases. However, in previous studies, transcanal endoscopic ear surgery was found to be a suitable means of providing a clear and magnified view for checking suspected areas for perilymphatic fistulae, with immediate reconstruction if necessary.[29] A temporal bone fracture was found in 32 ears in this study, but conservative management was successful.

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**Table 1.** Clinical and demographic characteristics of enrolled patients*

| Parameter | Cases | *P*-value |
|---|---|---|
| Age at time of surgery (mean ± SD; years) | 30.15 ± 8.71 | |
| Gender (*n* (%)) | | |
| – Male | 64 (47.1) | |
| – Female | 72 (52.9) | |
| Aetiology of head trauma (*n* (%)) | | |
| – Falling from height | 36 (26.5) | |
| – RTA | 52 (38.2) | |
| – Blow to head | 29 (21.32) | |
| – Slap | 19 (13.9) | |
| Other associated ear findings (*n* (%)) | | |
| – None | 90 (66.2) | |
| – Facial palsy | 14 (10.29) | |
| – Temporal bone fracture | 32 (23.53) | |
| Laterality (*n* (%)) | | |
| – Right | 57 (41.91) | |
| – Left | 79 (58.1) | |
| Follow-up duration (mean ± SD; months) | 8.60 ± 2.31 | |
| Mean ABG (mean ± SD; dB) | | <0.001† |
| – Pre-operatively | 33.6 ± 4.61 | |
| – Post-operatively | 3.2 ± 1.85 | |
| Mean AC level (mean ± SD; dB) | | <0.001† |
| – Pre-operatively | 50.9 ± 6.35 | |
| – Post-operatively | 22.35 ± 3.27 | |
| Mean BC level (mean ± SD; dB) | | <0.07 |
| – Pre-operatively | 17.35 ± 2.65 | |
| – Post-operatively | 17.81 ± 2.42 | |

*Patients who underwent transcanal endoscopic ossiculoplasty for traumatic ossicular disruption with an intact tympanic membrane. Total *n* = 136. †Indicates significant difference. SD = standard deviation; RTA = road traffic accident, ABG = air–bone gap; AC = air conduction; BC = bone conduction

Facial nerve palsy was detected in 14 cases. The tympanic segment was the most affected part, as confirmed by pre-operative radiology and intra-operative surgical findings. This finding is in accordance with previous research.[30,31] In this study, selected cases of facial nerve injury were successfully managed by transcanal endoscopic ear surgery, without the need for canaloplasty or a post-auricle incision and mastoidectomy. Recovery of facial nerve function was evident within the follow-up period in operated cases. Cases with a radiologically suspected injury at a mastoid segment were scheduled for a transmastoid approach and were excluded from the study.

Post-operative closure of the air–bone gap to within 10 dB or less was achieved in all cases. This is in accordance with other studies evaluating ossiculoplasty.[23] These results are comparable to the audiological outcomes after microscopic ossicular chain reconstruction for traumatic ossicular injury in the literature.[4,32]

Undoubtedly, 3D CT reconstructions facilitated the diagnosis of ossicular disruption in the present study. In all cases, the senior radiologist (senior author MRG) could correctly diagnose the pathology pre-operatively, in 100 per cent of cases. The same percentage of radiological accuracy was also reported by Maillot *et al.*, who emphasised its important role.[5] Although surgical exploration remains the most accurate diagnostic and therapeutic method, this high sensitivity strongly favours 3D CT as an essential tool in the pre-operative preparation of these cases.

- Endoscopic exploratory tympanotomy is effective in the diagnosis and treatment of traumatic ossicular disruption in patients with an intact tympanic membrane
- Use of three-dimensional computed tomography reconstructed images with senior radiologist consultation should be considered in all cases
- This technique facilitates the pre-operative prediction of the ossicular problem
- Following a prepared algorithm when dealing with these lesions can aid intra-operative decision-making

The retrospective nature of the study and the lack of comparative group add to its limitations. Future research should include a larger group of patients, using a prospective design, and with possible comparison to reconstruction using a synthetic prosthesis, for further assessment.

## Conclusion

Transcanal endoscopic ear surgery is an effective tool in the diagnosis and management of cases of traumatic ossicular

**Table 2.** Possible ossicular disruption pathology in study group and its management

| Intra-operative lesion | Surgical procedure | Cases (*n* (%))* |
|---|---|---|
| Incudostapedial dislocation | Repositioning + bone cement | 48 (35.3) |
| Incus luxation | | 44 (32.4) |
| – Isolated incus luxation | Repositioning + bone cement | 36 (26.5) |
| – Incus luxation with stapedio-vestibular dissociation or stapes fracture | Repositioning + stapedotomy + bone cement | 8 (5.9) |
| Stapes suprastructure fracture | Stapedotomy | 12 (8.82) |
| Incus fracture (necrosis of long process) | | 17 (12.5) |
| – Sufficient length | Bone cement | 6 (4.41) |
| – Insufficient length | Incus interposition & bone cement | 11 (8.1) |
| Malleus fracture | Bone cement | 2 (1.5) |
| Incudomalleolar luxation | Repositioning + bone cement | 11 (8.1) |
| Stapedio-vestibular with incudostapedial dislocation | Stapedotomy | 2 (1.5) |

*Total *n* = 136

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injury with an intact tympanic membrane. Following a simplified approach can facilitate and hasten decision-making in these challenging cases.

**Competing interests.** None declared

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