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Feasibility of piezosurgery in management of cholesteatoma with retrotympanic extension

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Research Article

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Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10607161/v1

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Additional Declarations: No competing interests reported.

Title: Feasibility of piezosurgery in management of cholesteatoma with retrotympanic extension

Abstract:

Background: The application of piezoelectric technology in the otology field has gained traction recently, showcasing its ability to cut bone precisely without damaging the nearby soft tissue. The study aimed to determine the safety and efficacy of using a piezoelectric device in canal wall up mastoidectomy via a facial recess approach to eradicate middle ear cholesteatoma extending into the retrotympanic space.

Patient and Methods: A prospective cohort study conducted among 31 consecutive patients with middle ear cholesteatoma extending into retrotymanic spaces proved clinically and radiologically at our tertiary referral center in the period between February 2024 and January 2026. Post-operative complication (Facial nerve palsy, taste sensation, vertigo and SNHL), pain by visual analog scale (VAS; 0–10) and pure-tone audiometry in the follow up were recorded.

Result: Complete eradication of cholesteatoma reported in 29 patients (93.55%) after a follow up period of 17±4.16 months. Statistically significant improvement in AC and ABG postoperatively (p-value <0.001),while BC thresholds showed no significant difference (No SNHL),none of the patients developed facial nerve, or wound dehiscence, or vertigo injuries despite the presence of 3 patients (9.7%) with facial canal dehiscence .None of the patients experienced pain after 1 week post operatively.

Conclusion: Piezosurgery paired with a microdrill and microscope is yielding hopeful and promising outcomes in managing cholesteatoma that has spread to the retrotympanic region.

Keyword: Piezosurgery; Posterior tympanotomy; Retrotympanum cholesteatoma; Microscope; outcome

Introduction:

Middle ear cholesteatoma is marked by a sac filled with keratinized squamous epithelium, keratin debris, and a matrix of varying thickness, which may or may not be accompanied by an inflammatory reaction [1].The ultimate goal of cholesteatoma surgery is always the complete removal of the disease and ensuring the ear's safety. Although hearing restoration is always worth considering, it is typically treated as a secondary aim. The surgical treatment of cholesteatoma is controversial regarding the choice between canal wall down (CWD) and canal wall up (CWU) techniques and the requirement for staged surgeries[2]. Drills are traditionally viewed as the quintessential tool in cholesteatoma surgery. They represent a significant advancement in the development of otologic surgery. They are continually evolving to become more specialized and compact, featuring multiple heads and tips designed for various tasks that effectively cut through bone[3, 4]. For several years, piezoelectric technology has served as a surgical instrument or cavitating soft tissue, and more recently, it has been employed to cut bone using micro-vibrations. Its applications in surgery are expanding, as evidenced by the growing body of literature that discusses its role in cranial and spinal surgery, as well as in craniofacial, orbital, hand, and facial reconstructive surgery.[5]. This piezoelectric device generates low frequency ultrasonic waves at (25 to 30 kHz) by utilizing the piezoelectric effect, which modifies certain ceramics and crystals when an electric current passes through, creating an ultrasonic oscillation. The instrument’s power can be adjusted between (2.8 and 16) watts, depending on the bone density.The micro-vibrations generated in the piezoelectric hand-piece cause the inserts to vibrate linearly from 60 to 210 mm[6]. Navigating retrotympanic spaces in cases of cholesteatoma that

extend to the retrotympanum presents a significant challenge, making posterior tympanotomy a crucial method to enhance access to the facial recess and sinus tympani. However, performing a posterior tympanotomy entails a high risk of damaging critical structures like the facial nerve, chordae tympani, and jugular bulb[7]. Therefore, the need of piezosurgery has been advised in such procedure due to its soft tissue-preservation power without the fear to injure any critical structure specially the facial nerve. Recently, the use of piezosurgery in performing atticotomy during endoscopic tympanoplasties have been reported as it was efficient and safe to critical structure such as Facial nerve, chordae tympani and tympanomeatal flap[8]. Our current study focuses on evaluating the safety and efficacy of the piezoelectric device employed in canal wall up mastoidectomy via facial recess approach for the removal of middle ear cholesteatoma that invades the retrotympanic space.

Patients and Methods:

This study was a prospective cohort study conducted among 31 consecutive patients with middle ear cholesteatoma extending into retrotymanic spaces proved clinically and radiologically at [removed for blind review] our tertiary referral center in the period between February 2024 and January 2026. The study was approved by the [removed for blind review] Institutional Research Board prior to its conduction. We excluded revision cases, patients with preoperative facial nerve palsy, patients with dead ear or with only hearing ear.

Prior to surgeries, preoperative hearing status was evaluated by pure tone audiometry (PTA). In addition, cholesteatoma extension was evaluated by preoperative CT scan.

During all procedures, the (Leica M530 OHX) microscope was employed under general anesthesia. Surgeries commenced with an injection of 1/100,000 diluted adrenaline in the postauricular region and external ear canal.

After making a postauricular skin incision, the subcutaneous tissue was subsequently incised. Identification of the temporalis fascia was followed by harvesting a graft from this area. Creation of a U-shaped periosteal flap was done, followed by elevation of the periosteum. The external auditory canal was incised to create a window, allowing for trimming of the perforation edges. Elevation of the tympanomeatal flap continued to the tympanic annulus, which was subsequently dislodged out of the sulcus.

Cortical mastoidectomy was then performed using traditional microdrill. The cholesteatoma sac was located inside the antrum and was dissected by the surgeon towards the middle ear. The lateral canal and short process of incus were identified.

Posterior tympanotomy was performed using the piezosurgery device (Guilin Woodpecker Medical Instrument) which consist of one hand piece, three to four tips of piezo bone surgery models (US4, UL1, UL3, UI3) (Fig.1). In the beginning, we used the UL1 tip of piezo device to carve the posterior canal wall to provide better visualization of the mastoid segment of the FN as we make the posterior canal thinner. The short process of the incus approximates the location of the genu. Perhaps the most important landmark, however, is a properly thinned posterior bony canal wall (Fig.2).

Retrotympanum spaces were identified as well as any residual cholesteatoma was breached easily so it was resected safely under direct vision even in the cases where the cholesteatoma was in close adherent to the mastoid portion of the FN as seen in (Fig.2).

At this point, we were able to define and open of the facial recess that provided us the access to the middle ear. The promontory, round window niche, incudostapedial joint and cochleariform process were visualized through the facial recess (Fig.2). Complete eradication of the cholesteatoma was accessible including the hidden cholesteatoma extended to the retrotympanic space.

The cholesteatoma was removed from the middle ear, allowing us to evaluate the incus, stapes, and malleus, and to visualize the facial canal. (Fig.2).

When ossicular discontinuity was identified, a reconstruction of the ossicular chain was carried out. Conchal cartilage was used for interposition in instances of partial necrosis of the long process of the incus, and a refashioned incus was positioned between the relocated malleus and the stapes suprastructure in cases of complete necrosis of the long process of the incus. (Fig.2). Tympanic membrane was reconstructed by the previously harvested temporalis fascia graft and gel foam insertion over the graft, then closure of wound and skin in layers (Fig.2).

Post-operative data: Post-operative complication (Facial nerve palsy, taste sensation, vertigo and SNHL. During the follow up, we assessed pain using a visual analog scale (VAS;0–10) and conducted endoscopic evaluation, CT scan, and pure-tone audiometry.

Results:

Thirty-one patients were included in the study. Their mean age ± SD was 35.97±15.11 years. Fourteen patients (45.2%) were females while seventeen patients (54.8%) were males. In 16 patients the operated ear was the right ear 16 while in 15 patients was the left (Table 1).

Intact ossicular chain was found in 2 patients (6.45%). Partially necrosed incus long process was found in 13 patients (41.94%) and was reconstructed by cartilage interposition. Completely necrosed incus long process was found in 16 patients (51.61%) and was reconstructed by Malleus relocation incus interposition (Table 2).

Hearing results are presented in (Table 3). Pre- and postoperative AC thresholds±SD were 40.99±4.21 and 21.32±4.92 dB A statistically significant difference (P value <0.001) was observed respectively. The difference between pre- and postoperative BC thresholds±SD, which were 10.05±3.87 and 10.39±4.06 dB respectively, was statistically non-significant (P value 0.281). ABGs±SD before and after the procedure were 30.88±4.71 and 10.94±6.63 dB respectively, showing a statistically significant difference (P value <0.001).

In this study, complete eradication of cholesteatoma was reported in 29 patients (93.55%) after a follow up period of 17±4.16 months. None of the patients had residual cholesteatoma while 2 patients (6.5%) developed recurrent cholesteatoma (Table 4).

As regard post- operative complication, none of the patients developed facial nerve, sigmoid sinus or dural injuries despite the presence of 3 patients (9.7%) with facial canal dehiscence and 2 patients (6.5%) with lateral semicircular canal dehiscence. In addition, none of the patients developed post-auricular wound dehiscence, vertigo or post- operative SNHL. Three patients (9.7%) had altered taste sensation 1 week postoperatively, that improved within 3 months. Three patients (9.67%) experienced severe postoperative pain (VAS values were >4) at the first postoperative day and was managed by simple analgesics. However, after 1 week, none of the patients who experienced pain (Table 4). Mean±SD operative time was

123.81±12.78 in min, the minimal duration was 100 min and maximum duration was 160 min.

We conducted an immediate post-operative follow-up to detect any facial nerve involvement, followed by follow-up visits every 1-2 weeks to remove dressings or sutures, at 1 month, and finally at 3 months. Between 6- and 12-months post-surgery, we carried out a complete evaluation that included endoscopic examination, MRI petrous bone imaging, and hearing assessment (audiometry), and compared these findings with preoperative data.

Discussion:

Although different techniques of cholesteatoma surgery have been erupted, developed and modified over the years by otologists, but the eradication of the pathology safely was always the ultimate goal of surgery regardless the technique and various tools that were used [9, 10].

Therefore, many tools (microscope, endoscope, microdrill and laser) had been used in cholesteatoma surgery, facilitating the different approaches (CWU and CWD mastoidectomy) used in eliminating cholesteatoma according to its extension and indications [11-14].

Piezosurgery is considered as innovative surgery that developed from the ultrasound technique as a cutting tool to selectively cut mineralized tissues as bone while preserving the surrounding soft tissue, the earliest attempts was reported for the first time since 1957 in cutting of dento-osseous structures, as well as, in medicine was described in 1972 for thoracic surgery [15-18].

In our current study, we used microscope in combination with microdrill and piezosurgery for performing CWU mastoidectomy with posterior tympanotomy in cases of cholesteatoma with retrotympanic extension to evaluate the safety & the

efficacy of the piezoelectric device. This is considered a new combination of tools, as the published scientific papers were few.

Thirty-one patients participated in this research. According to the AAOHNS, hearing outcomes were compared pre and postoperatively via PTA after the hearing mechanism was restored with a temporalis fascia graft and ossicular reconstruction; this involved assessing air conduction, bone conduction, and air bone gap at 0.5, 1, 2, and 3KHz. [19, 20].

In the present study, postoperative audiological assessment demonstrated statistically significant improvements in both air conduction (AC) thresholds and the air–bone gap (ABG) compared with preoperative measurements ($p < 0.001$). These findings are consistent with those reported by **Elbialy et al. (2023),** who observed significant hearing improvement in 43 patients undergoing canal wall-up (CWU) mastoidectomy for cholesteatoma with retrotympanic extension, including 11 patients who underwent posterior tympanotomy without the use of piezosurgery [21].

Analysis of bone conduction (BC) thresholds revealed no statistically significant difference between preoperative and postoperative measurements. This finding is consistent with the results reported by **Chen CK et al. (2024),** who likewise observed no significant change in bone conduction thresholds following endoscopic atticotomy using piezosurgery in patients with attic cholesteatoma [22].

Elgarf et al (2025) ***''Piezoelectric endoscopic management of attic cholesteatoma and retraction pocket"*** who enrolled 30 patients in their study who had attic cholesteatoma managed by Trans-canal endoscopic technique combined with piezoelectric device for the bony work, they stated that the mean operating time was 115 min , about 8 min less in operating time in comparison to our study (123.81

min).However, we performed CWU mastoidectomy with facial recess approach using microscope combined with the piezoelectric device for more extended cholesteatoma to the retrotympanic space and this consumed more time [22].

The current study demonstrated a cholesteatoma eradication rate of 93.5%, with successful disease control in 29 of the 31 patients following a mean follow-up duration of 17 months. Recidivism was detected in the remaining two patients, representing a rate of 6.5%. A comparable outcome was reported by **Salami et al. (2010)** in their study entitled ***"Piezosurgery versus microdrill in intact canal wall"*** where recurrence occurred in only one of the 30 patients treated with piezosurgery (3%) after 12 months of follow-up [23].

Maintaining facial nerve integrity remains a major challenge in otologic surgery, particularly during cholesteatoma removal in cases of extensive disease and distorted anatomical landmarks, especially when performing posterior tympanotomy. In the present study, no intraoperative or postoperative facial nerve injuries were observed, despite the presence of facial canal dehiscence in three patients (9.7%). These findings support the potential safety of piezosurgery in procedures involving the facial nerve and are consistent with the observations of **Salami et al. (2008)** in their study, ***"A novel approach to facial nerve decompression: use of Piezosurgery,"*** which highlighted the soft-tissue safety of this technique and reported no adverse effects following inadvertent contact with the facial nerve.[24]

The favorable safety profile of piezosurgery may be attributed to the digital modulation of ultrasonic oscillation frequencies and the high-flow irrigation system, which enhance surgical precision and control while minimizing thermal damage to the bone during osteotomy. Furthermore, this technique provides improved

intraoperative visibility through its hemostatic effect, resulting in a relatively bloodless surgical field. [25]

Although we reported only 3 patients (9.7%) had altered taste sensation 1 week postoperatively, but there was no permanent loss of taste as in subsequent follow ups the patients declared that the taste already improved

Postoperative pain was assessed over the first seven days following surgery. At the end of this period, patients were asked to evaluate their pain intensity using a 100-mm visual analogue scale (VAS), scored from 0 to 10, where 0 indicated the absence of pain and 10 represented the maximum imaginable pain. Pain scores were based on the patients' subjective assessments, when VAS values were >4 (moderate to severe pain), ketolac 30 mg IM was administered and noted. There were 3 (9.67%) patients who experienced severe postoperative pain at the first day of surgery. On the other hand, there were no patients who experienced moderate to severe pain after 1 week. This finding was consistent with **Crippa et al (2011)** who reported less postoperative pain in the group that underwent CWU mastoidectomy using piezoelectric device in comparison to another group that underwent CWU with conventional microdrill [26].

Limitation of work:

1-Follow up period was relatively short 17months.

2-Small sample size.

3- Nevertheless, the widespread adoption of piezosurgery remains challenging due to the substantial cost of the device, its limited accessibility in many healthcare institutions, and the requirement for adequate surgeon training and technical expertise.

Conclusion:

The findings of the present study indicate that the combined application of piezosurgery, microdrill, and microscopic visualization may offer a promising surgical approach for the management of cholesteatoma with retrotympanic extension, potentially facilitating precise disease removal while minimizing the risk of injury to adjacent critical structures.

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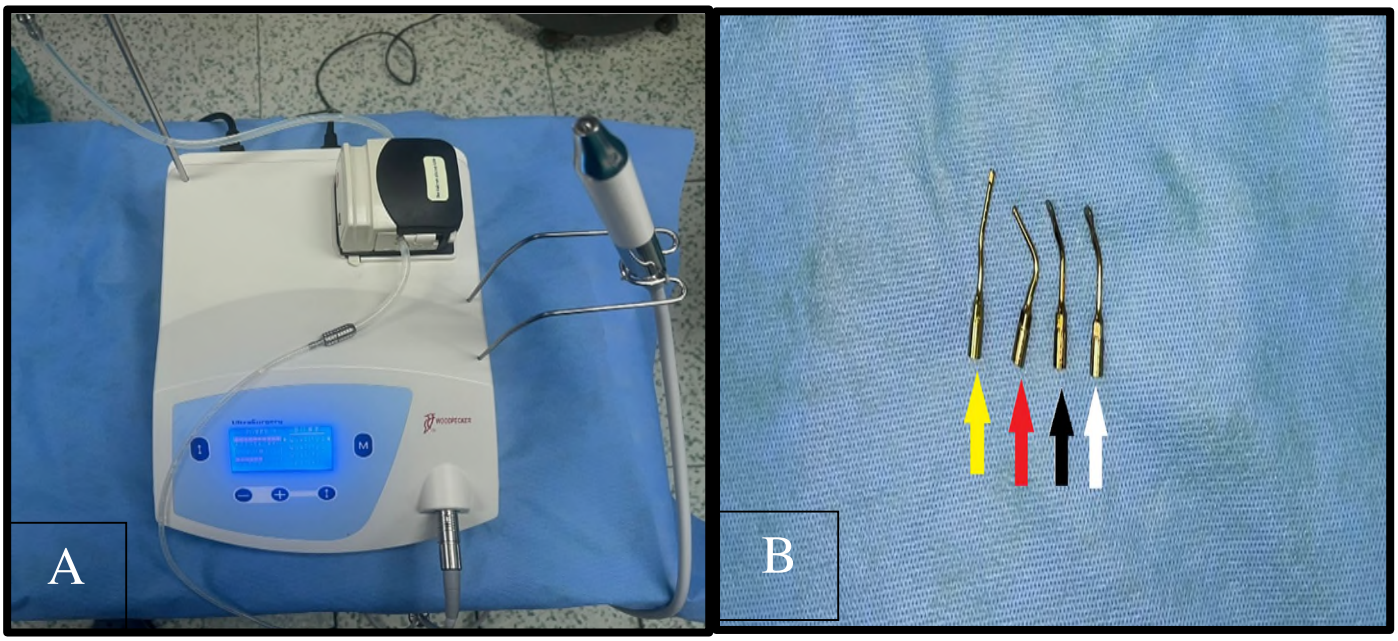


Figure 1 : A: The piezosurgery device (Woodpecker Piezo Ultrasurgery) with one hand piece and one bump connected to physiological solution, **B**: The different tips used in posterior tympanotomy step: white and black arrows: US4& UL1 (used in bone remodling), red arrows:UL3 (diamond coated) used for extended posterior tympanotomy , yellow arrow: UI3 (irrigation from tip point)used for irrigation of narrow field in retrotympanic spaces.

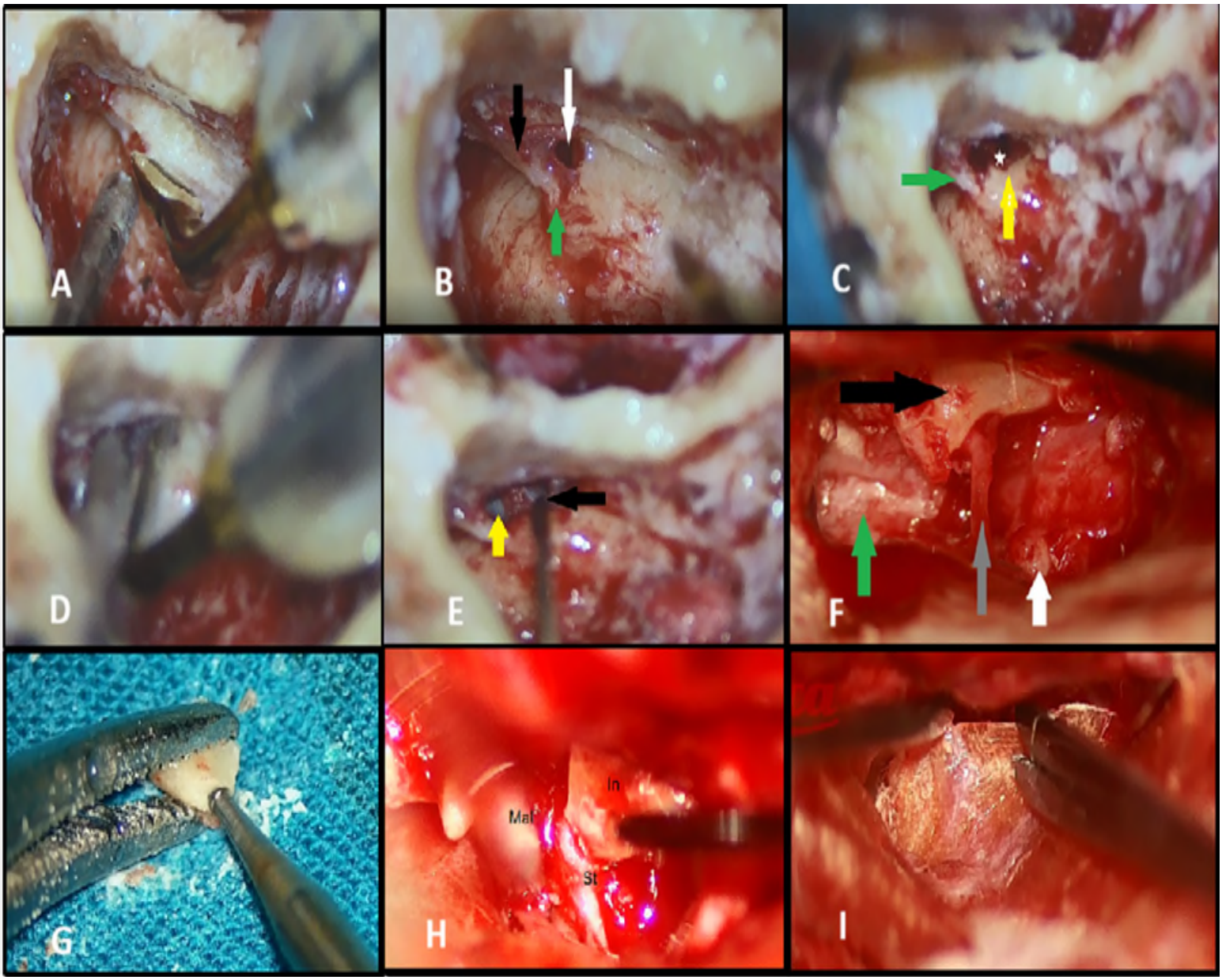


Figure 2: The Surgical steps: (A) The carving procedure of the posterior canal wall in medial to lateral manner till adequate exposure of mastoid segment of Facial nerve and fossa incudes, **(B)** Exposure of Facial recess and identify : incus short process (black arrow) , second genu of FN (green arrow) posterior tympanotomy (white arrow), **(C)** Exposure of Facial recess and identify: incus short process (green arrow), mastoid segment of FN (yellow arrow), facial recess containing residual cholesteatoma (white asteric), **(D, E)** the use of pizo electric device in extending the the posterior tympanotomy inferiorly by carving the chordal ridge to provide better visualization and accessibility of retrotympanic spaces , oval window (yellow arrow) , round window nich (black arrow).**(F)** Visualization of middle ear contents after tympanomeatal flap elevation attic cholesteatoma (green arrow), head of malleus (black arrow), head of stapes (white arrow), chorda tympani (blue arrow), note that incus was necrosed and removed, **(G)** Drilling a hole in the removed incus for stapes head using 1-mm fine diamond bur.**(H)** placing the refashioned incus on the stapes and under the malleus. Mal: malleus, St: Stapes, In: Incus. **(I)** Placing of temporalis fascia graft

Table (1): Demographic data of patients in the study:

	n=31	**%**
Age (years) **Mean±SD** **(Min-Max)**	 35.97±15.11 (17-66)	
Sex **Males** **Females**	 17 14	 54.8 45.2
Affected side **Right** **Left**	 16 15	 51.6 48.4

Table (2): Ossicular conduction and ossiculoplasty among studied cases:

Ossicular condition and ossiculoplasty type	**N**	**%**
Intact → no ossiculoplasty	2	6.45%
Partially necrosed incus long process → cartilage interposition	13	41.94
Completely necrosed incus long process → Malleus relocation incus interposition	16	51.61%

Table (3): Comparison between preoperative AC, BC and ABG:

	Pre operative	**Post-operative**	**Test of significance**
AC	40.99±4.21	21.32±4.92	t=18.45 *P* <0.001*
BC	10.05±3.87	10.39±4.06	t=1.09 *P*=0.281
ABG	30.88±4.71	10.94±6.63	t=18.87 *P*<0.001*

Data expressed as mean ±SD , t: Paired t test , *statistically significant

Table (4): Post-operative complications among studied cases:

Post-operative complications	**N**	**%**
Taste disturbance	3	9.7
wound dehiscence	0	0.0
post-operative pain (moderate to severe) at first day	3	9.67
post-operative pain (moderate to severe) after 1 week	0	0.0
Vertigo	0	0.0
SNHL	0	0.0
Facial nerve injury	0	0.0
Eradication of cholesteatoma incidence in mean follow up period (17 months)	29	93.5
residual	0	0.0
recurrence	2	6.5

Supplementary Files

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