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Suprameatal – trans-zygomatic root endoscopic approach to the geniculate ganglion: an anatomical and radiological study.

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Suprameatal – trans-zygomatic root endoscopic approach to the geniculate ganglion: an anatomical and radiological study.

Abstract

Purpose: To describe the suprameatal-transzygomatic root endoscopic approach (STEA) to the geniculate ganglion (GG), the labyrinthine facial nerve (FN) and epitympanum.

Methods: The feasibility and limits of the STEA, maintaining the integrity of the ossicular chain, was analysed. Ten human cadaveric ears were dissected. Step-by-step description of the technique and relevant measurements were taken during the approach. The visualization and surgical working field on the anterior and posterior medial epitympanum, GG, greater superficial petrosal nerve, the labyrinthine FN and supra-geniculate area were evaluated. The range of motion through the approach and the rate of the decompression of the GG and the labyrinthine portion of the FN were assessed as well. CT-scan measurements were compared with those obtained during the dissection.

Results: A complete exploration of the epitympanum was possible in every specimen. Decompression of the GG and first portion of the FN was achieved without any trauma to the ossicular chain in 9 ears. The endoscope movements were mainly limited by the distance between bony buttress-short process of the incus-tegmen. The working space, during GG and labyrinthine FN decompression, was limited by the distance between malleus head-medial epitympanic wall and malleus head-GG. Radiologic measurements were consistent with those obtained during the dissections.

Conclusion: The STEA is a promising minimally invasive approach for decompression of the GG and FN's labyrinthine portion. The applications of this corridor include the exploration and surgery of the medial epitympanum, preserving the ossicular chain.

Keywords: facial nerve, geniculate ganglion, facial nerve decompression, epitympanum, endoscopic ear surgery

Declarations

All the authors approved the manuscript.

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Introduction

Different surgical approaches to the geniculate ganglion, peri-geniculate area, labyrinthine segment of the first portion of the facial nerve have been described in the literature[1-10]. They can be grouped into middle fossa approach, the trans-mastoid approaches, and the trans-canal endoscopic approach. All those approaches, have advantages and some anatomical and functional limitations. Middle cranial fossa approach (MCFA) provides the best exposure of the geniculate ganglion and first portion of the facial nerve, allowing a good exposure either of the labyrinthine or internal auditory canal segment of the facial nerve. Furthermore, to date is the only approach which permits to maintain the integrity of the ossicular chain. It is, however, an invasive approach which requires craniotomy and temporal lobe retraction, with the risk of postoperative complications such as seizures, intracranial bleeding, postoperative SCF leak and accidental damage of the ossicular chain[11]. Iatrogenic injury to the geniculate ganglion has been also described during this approach, in case of a dehiscent geniculate ganglion[12]. The trans-mastoid approaches (TMA) to the geniculate ganglion area have been developed as less invasive alternative to the MCFA. Nonetheless, the main limitations of this approach are the limited anatomical indications and the need for malleus head and incus removal. Finally, the transcanal fully endoscopic approach (TCEA) is less invasive than the trans-mastoid approach, and overcomes many of the anatomical limits of the microscopic transmastoid approaches[6-8,13]. However, as for the TMA approach it requires the removal of malleus head and incus to gain access to the geniculate ganglion area, requiring ossicular chain reconstruction. In addition, it offers a very limited exposure of the intra-labyrinthine portion of the facial nerve, if cochlear integrity and hearing preservation is desired.

The aim of the present study was to explore an alternative route to the geniculate ganglion and the labyrinthine portion of the facial nerve through a suprameatal - transzygomatic root endoscopic approach (STEA). An anatomical and radiological study analysed the feasibility and limits of the new approach to the geniculate ganglion area and intra-labyrinthine portion of the facial nerve, maintaining the integrity of the ossicular chain.

Methods

Cadaveric dissections

All the cadaveric dissections were performed at the Human Anatomy Institute of the University of Bologna from June 2017 to February 2020. Cadavers were obtained from the cadaver donation program of the Department of biomedical and neuro-motor sciences of the University of Bologna (DIBINEM), and their dissection was approved for scientific purposes. This study did not require ethic committee approval. The procedures used in this study adhere to the tenets of the declaration of Helsinki.

The STEA was performed on 10 silicon-injected and formalin fixed human cadaveric ears. Step by step description of the technique and relevant measurements during each step were taken to explore the feasibility and limits of the approach. Measurements were obtained by means of a small and flexible measuring strip, positioned by the surgeon during the dissection, with a maximum precision of 0.5 mm. Distances inferior to 2 mm were measured with 0.5, 1 and 1.5 mm long microhooks. Table 1 and 2 describe the measurements obtained on the specimens to assess the limits the approach.

The feasibility of the approach was evaluated in the different specimens in terms of visualization and proper surgical working field on the anterior and posterior medial epitympanum, geniculate ganglion area, greater superficial petrosal nerve, intra-petrosal tract of the first portion of the facial nerve and supra-geniculate area.

The proper surgical working space was assessed by 3 surgeons with different experience in endoscopic ear surgery (respectively 1 year, 5 years and 12 years). The range of motion through the approach of the endoscopes, surgical dissectors, bone curette, and drills were subjectively evaluated in the antero-posterior and inferior-superior axis, with a 5 points Liekert scale, as reported in table 3. The possibility to complete the decompression of the geniculate ganglion and the labyrinthine portion of the facial nerve, avoiding contact between surgical instruments with the incudal-malleolar joint, was assessed as well. Trauma or subluxation of the ossicular chain was finally evaluated.

Surgical technique

Positioning and instrumentation

Cadavers were positioned in supine position with a 45 degrees rotation of the head towards the contralateral side. The position was the same as in routine endoscopic middle ear surgery.

A 3-mm-diameter and 15-cm-long 0° and 45° endoscopes, and a 4-mm-diameter and 18-mm-long 0° and 45° endoscope (Karl Storz GmbH, Tuttlingen, Germany) were used and tested in all the anatomical specimens. A 3 CCD camera was used to record intraoperative images illustrating the approach.

Suprameatal keyhole access

A modified Shambaugh's incision extended from between the tragus and helix root and turning posteriorly to the superior auricular sulcus was performed to expose the suprameatal area and zygomatic root (figure 1). Identification of the superior wall of the external auditory canal was performed after the incision and a retractor was used to expose the area of drilling. Cortical bone was exposed with periosteum dissectors.

A Keyhole drilling area was created in the supra-meatal region as shown in Figure 1. The tegmen tympani and the superior wall of the external auditory canal were skeletonized without exposing the dura of the middle fossa, until reaching the epitympanic space under microscopic or magnifying Loup view. A posterior extension of the approach towards the aditus-ad-antrum and anterior antrum area may be created to increase the surgical field.

Endoscopic procedure

A 0° - 3 mm-diameter endoscope was inserted through the supra-meatal access (Figure 1). The lateral semicircular canal, the body and short process of the incus are identified and used as anatomical landmarks. Then, the drilling continues under endoscopic control. The endoscope is positioned posteriorly and the surgical instruments anteriorly. Thinning of the superior wall of the external auditory canal is completed in its medial portion under visual control of the incus.

The medial portion of the posterior epitympanum is then visualized and the lateral semi-circular canal, and second portion of the facial nerve can be easily detected. At this point, the endoscopic exploration with 0° and 45° lenses permit to explore the whole posterior medial and lateral epitympanum (figure 2). Furthermore, the tympanic isthmus, long process of the incus, incudal-stapedial joint, the tensor tympani tendon and the tensor fold can be visualized (figure 2). The cog limits the vision of the anterior epitympanum and can be used as a landmark (if complete) to identify the geniculate ganglion area, as described in other studies[14]. Drilling out of the cog permits to accede the anterior epitympanum and obtain a complete control of the anterior epitympanum, observing the incudal-malleolar joint from above. The tympanic diaphragm can be entirely explored without detaching the suspensor ligament of the malleus. The geniculate ganglion area can be identified medially to the cochleariform process (figure 2). The same exploration of the epitympanic area can be performed with 4mm-diameter 0° and 45° endoscopes.

Uncovering the geniculate ganglion, the labyrinthine segment of the first portion of the facial nerve and GSPN can be then performed with a 2 mm diamond burr and a small bone curette. The authors found that the posterior positioning of a 0 °- 3 mm endoscope and an anterior positioning of the instruments through the supra-meatal access was the most comfortable setting for this surgical step. The cochleariform process and the second portion of the facial nerve can be used as landmarks during the dissection of the geniculate ganglion area. The labyrinthine portion of the facial nerve can be identified after uncovering the geniculate ganglion removing progressively the dense bone of this area, drilling in an inferior, medial and posterior direction (figure 3). Attention to avoid opening of the posterior labyrinth and cochlea should be paid during this step as in classical decompression of the first portion of the facial nerve [1-5].

Radiologic assessment

Radiologic images were obtained with a cone-beam CT scan from 6 out of 10 dissected cadaver ears.

Measurements were carried out with OsiriX software (Pixmeo SARL company, Switzerland). The measurements were obtained in the axial and coronal plane and were compared with the anatomical measures obtained during the cadaveric dissection. Radiological measures compared with endoscopic view are depicted in figure 4.

Statistical analysis

Correlation between endoscopic and radiologic measurement were calculated with Pearson's test. The agreement between radiologic and endoscopic measurements was assessed by means of Bland-Altman plots (for significantly correlated values). Proportional bias was ruled out by linear regression (difference between measurements as dependant variable and average of the measurements as the independent variable), assuming non-significant results as indicating the absence of proportional bias. Statistical significance was set at p value < 0.05, with a confidence interval (CI) of 95%.

Results

Ten anatomic dissections were carried out on 10 ears from 8 cadavers heads. The dissected side was the right in 4 and the left in 6 cases. A complete exploration of the medial and lateral epitympanum was possible in all the specimens. Decompression of the geniculate ganglion and first portion of the facial nerve was completed and feasible without any direct trauma to the ossicular chain in 9 out of 10 ears.

Endoscopic measurements

Measurements obtained during anatomic dissections are reported in table 1 and 2. The diameters of the external approach ranged from 15 to 20 mm (antero-posterior). The inferior-superior measures of the external approach were narrower anteriorly (mean 5.4, range 4 -6 mm), compared with in the central third (mean 6.4, range 6-7 mm), and the posterior third (mean 7.7, range 7-9 mm).

The narrowest points limiting the endoscope movements (table 3) were the distance between the bony buttress (bone of fossa incudis), short process of the incus and tegmen (respectively mean 6.6, range 5.5-7 and 5.9, range 4.5 – 8mm). The points limiting the working space for surgical instruments and drill (table 3) in the decompression of geniculate ganglion and labyrinthine portion of facial nerve (avoiding direct trauma to the ossicular chain), were the distance between malleus head the medial epitympanic wall (mean 2.8, range 1- 4 mm) and between the malleus head and geniculate ganglion (mean 2.6, range 1.5 – 4 mm). In particular the only case of our study where a decompression of the geniculate ganglion and labyrinthine portion of the facial nerve was not feasible without direct trauma to the ossicular chain, had a distance between the malleus head and medial epitympanic wall of 1 mm, a dehiscent geniculate ganglion (in contact with the dura), a distance between malleus head and tegmen of 1 mm and a distance between the malleus head and geniculate ganglion of 1.5 mm.

Radiologic measurements

Radiologic measurements and their agreement with endoscopic measurements are reported in table 4. Radiologic measurements of the specimens were consistent with those obtained during the anatomic dissection.

In particular, the distances which limit the range of movement of the endoscope and instruments overlap closely with those obtained during anatomic dissection: distance between short process of the incus and tegmen (mean 6.47, range 5.23 – 8.11mm), distance between malleus head the medial epitympanic wall (mean 2.84, range 1.09- 4.18 mm) and between the malleus head and geniculate ganglion (mean 2.42, range 1.61 – 3.11 mm). The measurement of the distance between the bony buttress and tegmen, showed a significant proportional bias.

Complications

Among the 10 cadaveric dissections we registered complications in 3 cases. As previously pointed out, in case 6 the narrow space did not permit to avoid direct trauma to the ossicular chain and removal of incus and malleus head was necessary to complete the decompression. In the first 2 dissections, the drilling of the bone covering the first portion of the facial nerve was associated with injury of the cochlea in one and of the ampulla of SSC in the other.

Discussion

The MCFA represents the most popular approach to the geniculate ganglion area and first portion of the facial nerve. The main advantage of the MCFA is to permit a wide access to the geniculate ganglion area through the tegmen tympani from an extradural plane, avoiding the interruption of the ossicular chain. Pitfalls of this approach, are mainly related with its invasiveness, as it requires temporal craniotomy and temporal lobe retraction. Indeed, complications of MCFA, such as postoperative seizures, intracranial haemorrhage (epidural, subarachnoid and intraparenchymal), meningitis, cerebrospinal fluid leak, aphasia and hearing loss [11,15,16], although rare, can be serious. Although, the MCFA to the geniculate ganglion permits to maintain the ossicular chain integrity, a risk of conductive or sensorineural hearing loss, in case of ossicular chain trauma during the drilling of the tegmen tympani, is possible. In addition, the anatomical variability of the middle cranial fossa floor, may lead to a difficult identification of anatomical landmarks, with the possible risk of involuntary inner ear injury, particularly for surgeons without an extensive experience with this approach[17].

To avoid the risk of complications of the MCF approach, different trans-mastoid approaches to the geniculate ganglion have been developed. Their advantages consist of avoiding or reducing dura manipulation and temporal lobe retraction. They provide a limited access to the geniculate ganglion area and require removal of the incus and malleus head. In case of preservation of the bony tegmen, they are significantly limited by the anatomy of the epitympanic area, and spatial relationship between the posterior labyrinth and the geniculate ganglion, which reduce the feasibility of those approaches to a small percentage of patients with a favourable anatomy. Recently some authors described the radiologic criteria (petrous bone CT scan) which permit preoperatively to predict the feasibility of this type of approaches [7]. Other authors suggested to improve the limited visualization of the trans-mastoid approach with endoscopic assistance in a cadaveric study [18]. To gain adequate surgical exposure through this approach several reports suggest to uncover the middle cranial fossa dura through the TMA, to permit temporal lobe retraction, gaining a better exposure of the geniculate ganglion area [8-10]. However, those cases require extensive exposure of the dura, variable brain retraction and a solid reconstruction of the epitympanic and mastoid tegmen (e.g. cortical bone) to avoid postoperative dura and brain herniation into the mastoid and epitympanum. In addition, to the author's knowledge, there is not available data concerning the incidence of dura and brain herniation after those approaches in the long term.

Other less invasive approaches to the geniculate ganglion have been introduced more recently to avoid a temporal craniotomy and brain retraction. The TCEA permits to reach the geniculate ganglion region through the natural corridor of the external auditory canal. That approach offers a direct access to the second portion of the facial nerve and to the geniculate ganglion, but it allows limited control of the first portion of the facial nerve, unless cochlear function had not to be spared [14]. Furthermore, it requires incus and malleus head removal to reach a good control of the geniculate ganglion area, thus it creates an interruption the ossicular chain. Indeed, as for transmastoid approaches, an ossiculoplasty is required to restore sound conduction. Although a good ossiculoplasty in this situation may achieve an air-bone gap closure, the manipulation of the ossicular chain carries the risk of sensorineural hearing loss and the final hearing result, especially in the long term, is not completely predictable.

The suprameatal endoscopic approach (STEA) is a new approach which has been ideated to avoid the major drawbacks of the middle cranial fossa, transmastoid and endoscopic-transmeatal approaches.

Our anatomic study showed the feasibility of the approach in all specimens. The external opening of the approach which permitted to decompress the geniculate ganglion and the labyrinthine portion of the facial nerve was small and rather constant. There was not the need to enlarge the external keyhole opening towards the mastoid, both for endoscopic exploration and for gaining adequate working space for instruments in the specimens. Nonetheless, it is possible to extend the external opening posteriorly towards the mastoid, as desired. The narrower points of our approach for the introduction of the endoscope and epitympanic exploration were the distance between the short process of the incus and/or bony buttress and the tegmen. However, a complete exploration of the epitympanum was possible in all cases. The narrowest points limiting the working space for the surgical instruments and drill were the distance between the malleus head and medial wall of the epitympanum (Figure 4), as well as the distance between the geniculate ganglion and malleus head. In cases where those distances were $\geq$ 2 mm, it was possible to safely perform the geniculate ganglion and intra-labyrinthine portion decompression, avoiding any contact of the surgical instruments with the ossicular chain. In cases with a predicted or observed difficult anatomy, after completing the endoscopic exploration of the epitympanum, in order to increase the safety of the approach, we can recommend a preliminary incus-stapes joint disarticulation, through a transcanal approach.

The good overlap between the measurements obtained during anatomic dissections and the radiologic assessment of the specimens, are encouraging in the view of a clinical application of the approach. Indeed, they can allow a preoperative prediction of feasibility of the approach for geniculate ganglion and labyrinthine facial nerve decompression. Although not impacting on the feasibility of the approach, it should be taken into account the disagreement found between the endoscopic and radiologic measurements of the distances between first portion of the facial nerve and dura. This disagreement, as well as the proportional bias found for the distance between bony buttress and tegmen, can be explained by the anatomical changes after bone drilling, which can have an impact on the endoscopic measurement.

In our series, we encountered one case out of ten (case 6), with absent pneumatization of the zygomatic root and poor pneumatization of the epitympanum, where the procedure of decompression of the geniculate ganglion and first portion of the facial nerve was unfeasible, without any direct trauma or interruption of the ossicular chain. However, even in this case with unfavourable anatomy, the endoscopic exploration of the medial epitympanum and geniculate ganglion area was still possible, without removing the incus and malleus head.

The complications observed in the study were caused by the lack of confidence (even for experienced endoscopic ear surgeons) with the endoscopic view provided by the approach. Both cases of inner ear injury occurred during facial nerve decompression in the first two approaches. Thus, cadaveric training with this approach can be advocated before translating this approach into clinical practice.

The approach permitted a complete visual control of the anterior and posterior epitympanum with a surgical point of view directed from above and from posterior to anterior (Figure 2). The visual control and the space for using surgical instruments under endoscopic view was adequate through this approach both in medial and lateral epitympanic areas, particularly in the posterior epitympanum area, without ossicular chain removal. Thus, the privileged point of view provided by this approach permits to work surgically in the medial epitympanum preserving the ossicular chain integrity. This finding extends the possible indications of the STEA to the intraoperative exploration and surgical treatment of cholesteatoma in the medial epitympanum. Indeed, it may be considered as a route to explore the medial epitympanum, which permits to spare both the mastoid mucosa and the ossicular chain. In addition, although further research is required to define the indications and limits in the clinical practice, it can be used in combination with the transcanal endoscopic approach, and it may be considered as an additional endoscopic surgical route in the attempt to preserve the ossicular chain during cholesteatoma surgery.

The main limit of the study was the limited number of dissected cadavers, which, of course, cannot cover the wide variability of this anatomical area. However, the identification of critic distances limiting the feasibility of the approach, along with the good overlap between radiologic and anatomic measurements, may allow a preoperative selection of patients.

Conclusions

The STEA is a novel and promising minimally invasive surgical approach for decompression of the geniculate ganglion and labyrinthine portion of the facial nerve, which permits to preserve the ossicular chain integrity. The privileged point of view provided by the approach can extend the possible applications of this corridor to the endoscopic exploration and surgery of the medial epitympanum, without interrupting the ossicular chain. A further study with a larger number of dissected ears is necessary to validate our results within a wider spectrum of anatomical variability.

References

1) House WE (1961) Surgical exposure of the internal auditory canal and its contents through the middle cranial fossa. Laryngoscope 71:1363-85.

2) Fisch U (1970) Transtemporal surgery of the internal auditory canal. Report of 92 cases, technique, indications and results. Adv Otorhinolaryngol 17:203-40.

3) Garcia-Ibanez E, Garcia-Ibanez JL (1980) Middle fossa vestibular neurectomy: a report of 373 cases. Otolaryngol Head Neck Surg 88:486-90.

4) Marchioni D, Alicandri-Ciufelli M, Piccinini A, et al. (2011) Surgical anatomy of transcanal endoscopic approach to the tympanic facial nerve. Laryngoscope 121(7):1565-1573.

5) Lee HK, Lee WS (2003) Microsurgical anatomy of the perigeniculate ganglion area as seen from the middle cranial fossa approach. *Ann Otol Rhinol Laryngol* 112(6):531-533.

6) Yanagihara N, Hato H, Murakami S, Honda N (2001) Transmastoid decompression as a treatment of Bell palsy. Otolaryngol Head Neck Surg 124:282Y6.

7) Kim J, Kim J, Park S, Lee WS (2011) Use of computed tomography to predict the possibility of exposure of the first genu of the facial nerve via the transmastoid approach. *Otol Neurotol*. 32(7):1180-1184. doi:10.1097/MAO.0b013e318229d495

8) Kim MW, Ryu NG, Lim BW, Kim J (2016) Temporal Lobe Retraction Provides Better Surgical Exposure of the Peri-Geniculate Ganglion for Facial Nerve Decompression via Transmastoid Approach. *Yonsei Med J*. 57(6):1482-1487. doi:10.3349/ymj.2016.57.6.1482

9) Takeda T, Takebayashi S, Kakigi A, Nakatani H, Hamada M (2010) Total decompression of the facial nerve - superior prelabyrinthine cell tracts approach. *ORL J Otorhinolaryngol Relat Spec* 71 Suppl 1:112-115.

10) Ulug T (2009) Zygomatic root approach. Acta Otolaryngol 129: 793Y800.

11) Ansari SF, Terry C, Cohen-Gadol AA (2012) Surgery for vestibular schwannomas: a systematic review of complications by approach. *Neurosurg Focus*. 33(3):E14.

12) Hamzaoğlu V, Beger O, Erdoğan O, et al. (2020) Radioanatomic Assessment of the Geniculate Ganglion Dehiscence and Dimension: A Cadaveric Study. *World Neurosurg*.134:e913-e919. doi:10.1016/j.wneu.2019.11.036

13) Alicandri-Ciufelli M, Fermi M, Di Maro F, Soloperto D, Marchioni D, Presutti L (2020) Endoscopic facial nerve decompression in post-traumatic facial palsies: pilot clinical experience. Eur Arch Otorhinolaryngol. 277(10):2701-2707. doi: 10.1007/s00405-020-05997-7.

14) Marchioni D, Soloperto D, Rubini A, Nogueira JF, Badr-El-Dine M, Presutti L (2016) Endoscopic Facial Nerve Surgery. *Otolaryngol Clin North Am*. 49(5):1173-1187. doi:10.1016/j.otc.2016.05.006

15) Andresen NS, Sun DQ, Hansen MR (2018) Facial nerve decompression. Curr Opin Otolaryngol Head Neck Surg 26(5):6.

16) Casazza GC (2018) Systematic Review of Facial Nerve Outcomes After Middle Fossa Decompression and Transmastoid Decompression for Bell's Palsy With Complete Facial Paralysis. Otol Neurotol 39(10):8.

17) Lee HK, Kim IS, Lee WS (2006) New method of identifying the internal auditory canal as seen from the middle cranial fossa approach. *Ann Otol Rhinol Laryngol*. 115(6):457-460. doi:10.1177/000348940611500610

18) Jufas N, Bance M (2017) Endoscopically-assisted transmastoid approach to the geniculate ganglion and labyrinthine facial nerve. J Otolaryngol Head Neck Surg. 46(1):53.

Figure Legends

Fig. 1 External view of the approach, left ear.

A: After Shambough's incision, the zygomatic root and superior wall of the external auditory canal is exposed (drilling area is visible on the zygomatic root). B: View of the external approach after entering the epitympanum, with measures. C: position of instruments during the endoscopic dissection, endoscope positioned posteriorly and surgical instruments anteriorly (e.g. suction). eac: external auditory canal; zr: zygomatic root; st: squama temporalis; lines: inferior-superior diameters of the external approach: a, anterior diameter; c, central diameter; p, posterior diameter.

Fig. 2 Endoscopic exploration of the epitympanum

A: 0° endoscope view, right ear. B: 45° endoscope view, left ear. T: tegmen tympani; mh; malleus head; lmf: lateral malleolar fold; limf: lateral incudo-malleolar fold; i: Incus; sp: short process of the incus; *: long process of the incus; s: stapes; fn-2: 2nd portion of facial nerve; lsc lateral semicircular canal; cp: cochleariform process, tf: tensor fold; cog: cog. AE: anterior epytimpanum.

Fig. 3 Decompression of Geniculate ganglion and labyrinthine portion of facial nerve.

A: left ear during drilling. B: left ear after geniculate ganglion and labyrinthine portion decompression; C: right ear after geniculate ganglion and labyrinthine portion decompression. d: drill; t tegmen tympani; mh: malleus head; i: incus; fn-2 2nd portion of facial nerve; lsc: lateral semicircular canal; GG: geniculate ganglion; fn-1: labyrinthine portion of facial nerve; cp: cochleariform process; tf: tensor fold.

Fig. 4 Radiological measures and endoscopic view left ear.

A: CT scan, coronal view posterior to geniculate ganglion. B: CT scan, axial view. C: endoscopic view 3mm-0° endoscope. aSCC: ampulla of superior semicircular canal. iac: internal auditory canal; ILiac: labyrinthine portion of facial nerve close to the internal auditory canal; ILpg: labyrinthine portion of facial nerve peri-geniculate ganglion (close to geniculate ganglion); 2°FNpg: second portion of facial nerve perigeniculate ganglion (close to geniculate ganglion); mh: malleus head. White lines on the left and black lines on the right (corresponding endoscopic and radiologic measurements): a: malleus head – tegmen; b: malleus head – medial wall of epitympanum, c: malleus head; aSSC: ampulla of superior semicircular canal.

Figure 1

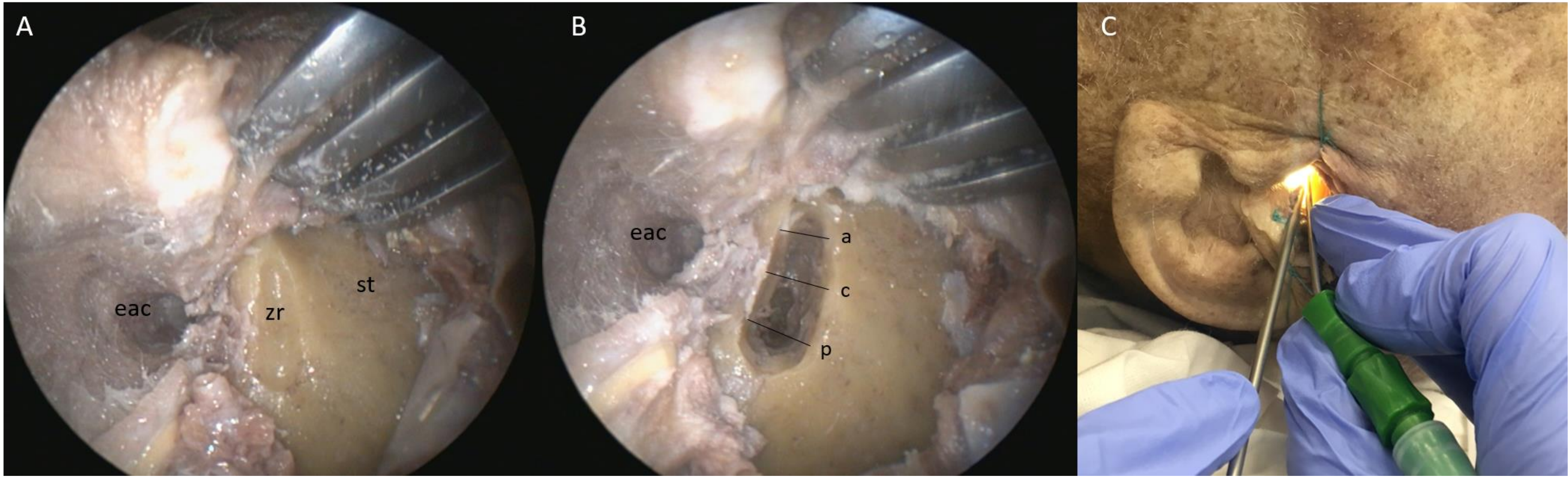

Figure 2

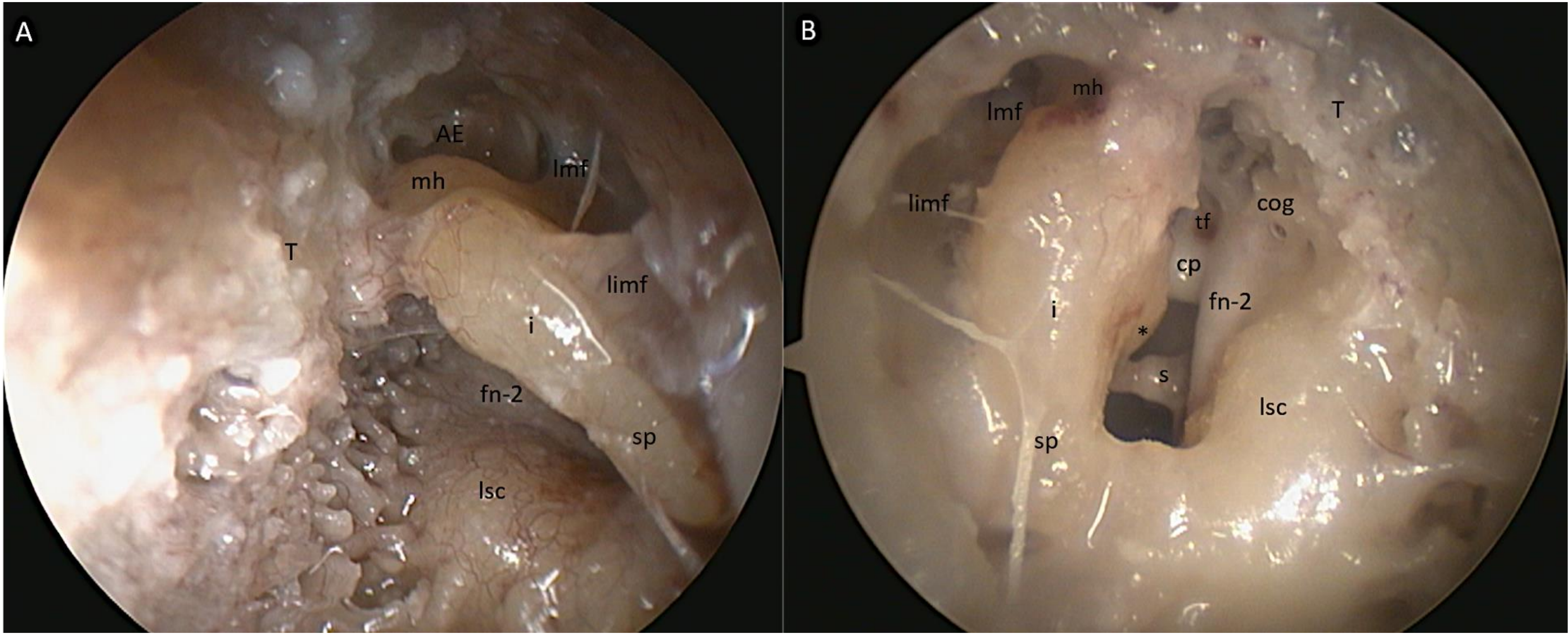
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Figure 3

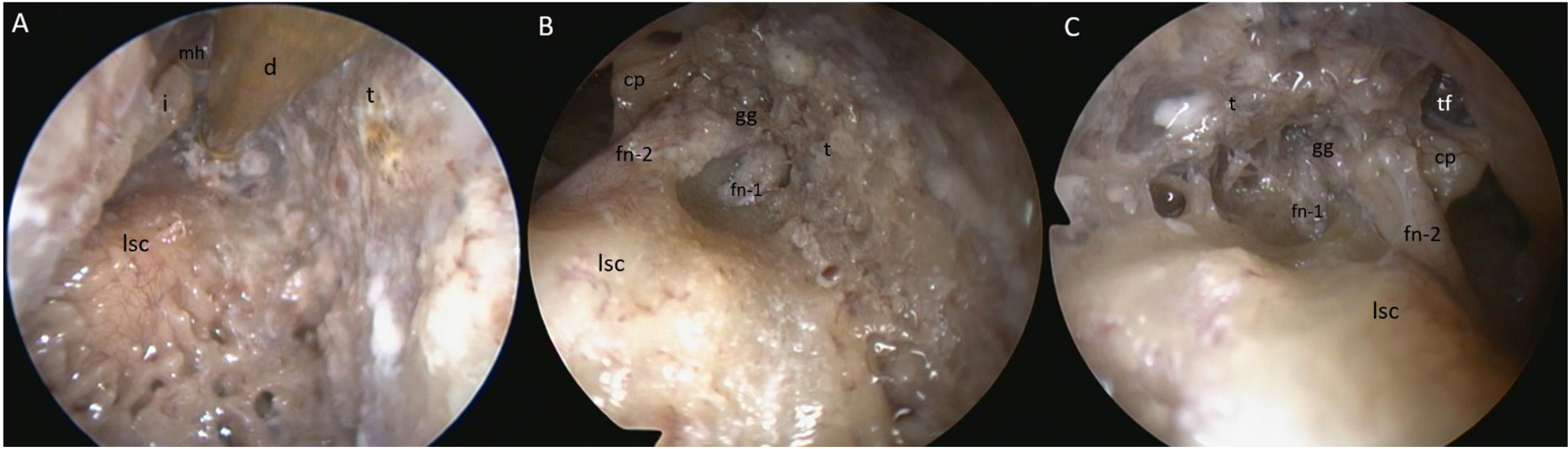
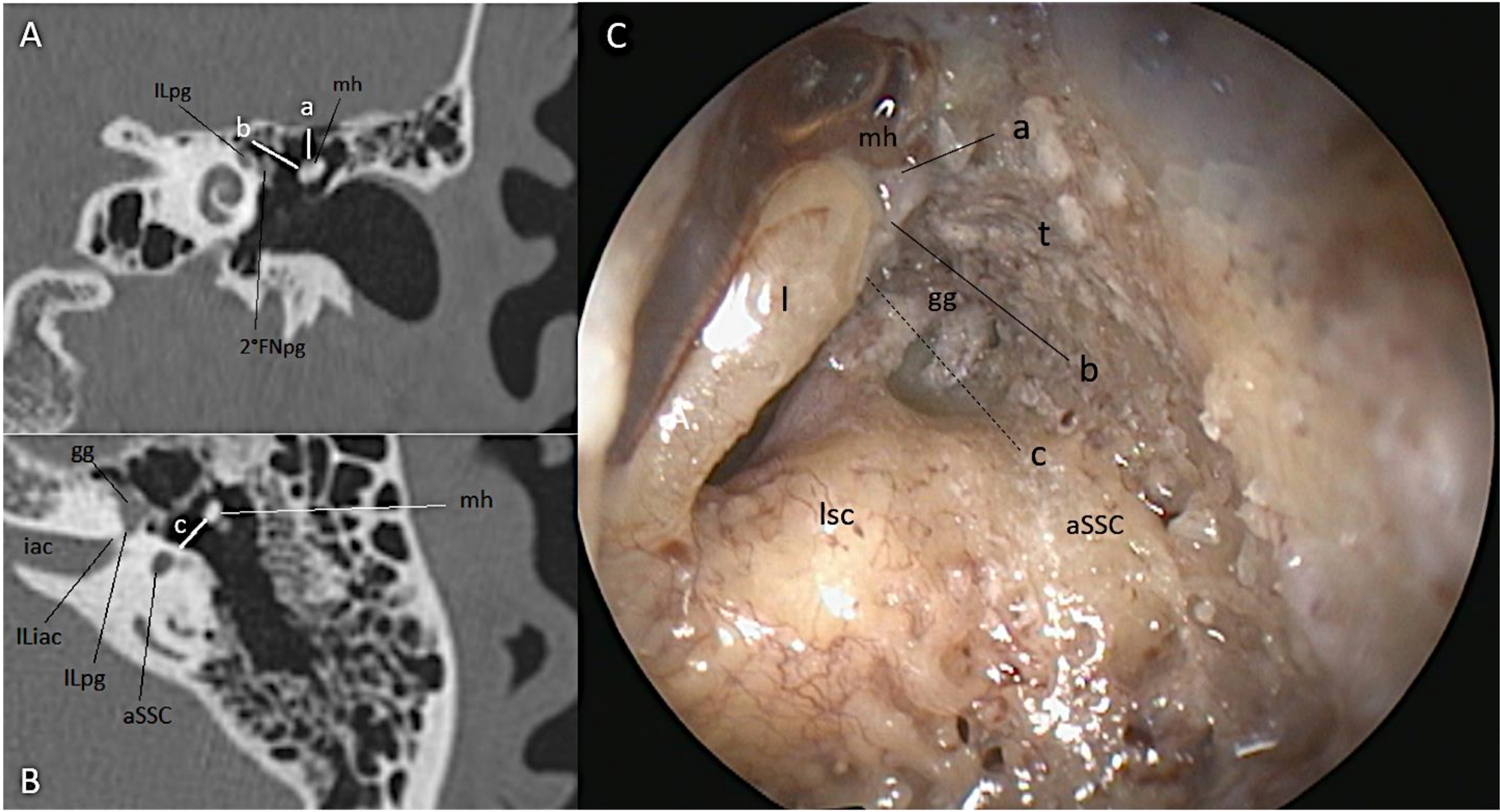


Figure 4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aSSC
B
C
mh
a
t
I
gg
b
c
lsc
aSSC

Table 1

Case	Side	External A - P	External I - S			BB - T	SPI - T	MH - T	MH-MEW	GG - MH
			P	C	A					
1	L	15	8	7	6	7	6	2	3.5	3
2	R	15	8	6	5	6	4.5	1.5	3	4
3	L	14	7	6	6	6	4.5	0.5	4	3
4	R	15	7	7	6	6	5.5	2	2	2
5	L	18	7	6	5	7	6	2	2	2
6	R	18	9	6	6	7	8	1	1	1.5
7	L	16	8	6	5	6.5	6	2.5	2.5	2.5
8	R	18	8	7	6	7.5	6.5	1	3	2.5
9	L	20	8	6	4	5.5	5	2	3	3
10	L	18	7	7	5	7	6.5	3	4	2

Table 1. Endoscopic measurements of the approach.

Distances are reported in mm. L: Left; R Right. Measures are reported in mm. External: external keyhole access measures (see figure 1); A: anterior; P: posterior; I: inferior; S: superior; C: Central. BB: bony buttress; T: tegmen. SPI: short process of the incus. MH: malleus head; MEW: medial epitympanic wall; GG: geniculate ganglion.

Table 2

Case	Side	GG -D	ILpg - D	ILiac - D	2°Fn - D	CP- D	aSSC - GG	aSSC- ILpg
1	L	1	1.5	4	3	3	4	2
2	R	1	1	5	5	3	5	2
3	L	1	1	3	4	2	5.5	3.5
4	R	2	3	4	4	4.5	6	4
5	L	1	2	3	3	5	4	2
6	R	0	1.5	3	5	3.5	3	2.5
7	L	2	4	3.5	4.5	3	3	5
8	R	2.5	3.5	4	5	5.5	4.5	3
9	L	1	1.5	2	2	3.5	2	2.5
10	L	1	1.5	2	4	5.5	3	3.5

Table 2. Endoscopic measurements relevant for geniculate ganglion and labyrinthine portion of facial nerve decompression, reported in mm.

GG: geniculate ganglion; D: middle cranial fossa dura, ILpg: 1° tract of facial nerve, perigeniculate labyrinthine portion (close to geniculate ganglion); ILiac: 1° tract of facial nerve, labyrinthine portion close to the internal auditory canal. 2°FN: second portion of facial nerve. CP: cocleariform process. aSSC: ampulla of the superior semicircular canal.

Table 3

	Range of motion				
	Endoscope 3mm	Endoscope 4 mm	Drill	Surgical instruments	Total
Expert A-P axis I-S axis Limiting distance	4 2 BB-T; SPI-T	3 1 BB-T; SPI-T	4 3 MH-MEW; MH-GG	5 4 MH- MEW; MH-GG	4 3
Intermediate A-P axis I – S axis Limiting distance	4 2 BB-T; SPI-T	3 1 BB-T; SPI-T	3 2 MH-MEW; MH-GG	5 4 MH- MEW; MH-GG	4 3
Beginner A-P axis I – S axis Limiting distance	3 2 BB-T; SPI-T	2 1 BB-T; SPI-T	2 2 MH-MEW; MH-GG	4 3 MH- MEW; MH-GG	3 2

Table 3. Subjective assessment of working space through the approach for geniculate ganglion and labyrinthine facial nerve decompression.

A-P axis: range of motion (Liekert scale from 0 to 5) in the antero-posterior axis. I-S axis: range of motion (Liekert scale from 0 to 5) in the inferior-superior axis. Limiting distance: distance between anatomical structures which limits the working space. Expert: experienced endoscopic ear surgeon; Intermediate: surgeon with intermediate experience in endoscopic ear surgery; Beginner: inexperienced endoscopic ear surgeon. BB-T: distance between bone of fossa incudis and tegmen. SPI-T: distance between short process of the incus and tegmen. MH-MEW: distance between malleus head and medial epitympanic wall. MH-GG: distance between malleus head and geniculate ganglion.

Table 4.

Case	**side**	**BB-T**	**SPI-T**	**MH-T**	**MH-MEW**	**MH-GG**	**D-GG**	**D-ILpg**	**D-ILiac**	**aSSC - GG**	**aSSC-ILpg**
5	L	6.9	6.2	2.1	2.23	2.08	1.04	2.3	3.2	4.24	2.31
6	R	7.12	8.11	2.09	1.09	1.61	0	4.1	5.1	2.56	2.45
7	L	6.66	6.04	2.81	3.01	3.01	2.5	2.3	6.8	3.21	5.12
8	R	7.41	6.5	1.12	3.32	2.54	2.61	3.1	5.1	4.67	3.8
9	L	4.55	5.23	2.21	3.23	3.11	1.11	1.5	2.1	2.41	2.56
10	L	7.08	6.7	2.97	4.18	2.14	1.07	1.5	2.2	3.11	3.3
Mean		6.62	6.04	2.21	2.84	2.41	1.38	2.46	4.08	3.36	3.3
SD		1.04	0.95	0.65	1.06	0.58	0.91	0.99	1.8	0.9	1.07
Mean difference		0.13	-0.13	-0.3	-0.26	-0.17	-0.14	-0.13	-1.16	-0.12	-0.17
Correlation sig. (p)		0.002*	<0.001*	0.026*	<0.001*	0.003*	<0.001*	0.79	0.042*	0.004*	0.004*
Agreement		yes	yes	yes	yes	yes	yes	no	no	yes	yes
Proportional bias Sig. (p)		0.028*	0.53	0.46	0.57	0.52	0.18	-	-	0.86	0.96

Table 4. CT scan measurements and corresponding agreement analysis with endoscopic measurements.

Distances are reported in mm. BB: bony buttress; T: tegmen. SPI: short process of the incus. MH: malleus head; MEW: medial epitympanic wall; GG: geniculate ganglion; D: middle cranial fossa dura; ILpg: Labyrinthine portion of facial nerve, peri-geniculate area (close to geniculate ganglion); ILiac: labyrinthine portion of facial nerve close to the internal auditory canal; 2°FN: secondo portion of facial nerve; CP: cochleariform process; aSSC: ampulla of the superior semicircular canal. Mean: mean radiologic value; SD (standard deviation); Mean difference: mean difference between endoscopic and radiologic measurement; Correlation: Pearson's correlation between endoscopic and radiologic measurements; Agreement: good agreement between endoscopic and radiologic measurements in Bland – Altman plots. Proportional bias: significant value corresponds to significant proportional bias between endoscopic and radiologic measurements, non-significant value corresponds to non-significant proportional bias (good agreement). *: statistically significant