Alma Mater Studiorum Università di Bologna
Archivio istituzionale della ricerca

Suprameatal–transzygomatic root endoscopic approach to the geniculate ganglion: an anatomical and radiological study

This is the final peer-reviewed author's accepted manuscript (postprint) of the following publication:

(Article begins on next page)

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

Ignacio Javier Fernandez, MD, FEBORL-HNS[1]; Matteo Fermi, MD[1]; Lucia Manzoli, MD, PhD Prof[2]; Livio Presutti, MD Prof [3].

[1] Otolaryngology Head and Neck Surgery Department, University of Modena, Modena, Italy.

[2] Institute of Human Anatomy, Department of Biomedical and Neuro-Motor Sciences (DIBINEM), University of Bologna, Bologna, Italy.

[3] Otolaryngology Head and Neck Surgery Department, University of Bologna, Bologna, Italy.

Corresponding author:

Ignacio Javier Fernandez, MD, FEBORL-HNS

ORCID 0000-0002-9120-6586

Otolaryngology Head and Neck Surgery Department

University Hospital of Modena (Policlinico di Modena, Università di Modena e Reggio Emilia, Via del Pozzo 71, 41124 Modena, Italy)

Email: ignaciojavier.fernandez@unimore.it ; ignafernandez@yahoo.it

Phone +39-059-4222402

1 **Suprameatal – trans-zygomatic root endoscopic approach to the geniculate ganglion: an anatomical**

2 **and radiological study.**

3

4 **Abstract**

5 **Purpose:** To describe the suprameatal-transzygomatic root endoscopic approach (STEA) to the geniculate

6 ganglion (GG), the labyrinthine facial nerve (FN) and epitympanum.

7 **Methods:** The feasibility and limits of the STEA, maintaining the integrity of the ossicular chain, was

8 analysed. Ten human cadaveric ears were dissected. Step-by-step description of the technique and relevant

9 measurements were taken during the approach. The visualization and surgical working field on the anterior

10 and posterior medial epitympanum, GG, greater superficial petrosal nerve, the labyrinthine FN and supra-

11 geniculate area were evaluated. The range of motion through the approach and the rate of the decompression

12 of the GG and the labyrinthine portion of the FN were assessed as well. CT-scan measurements were compared

13 with those obtained during the dissection.

14 **Results:** A complete exploration of the epitympanum was possible in every specimen. Decompression of the

15 GG and first portion of the FN was achieved without any trauma to the ossicular chain in 9 ears. The endoscope

16 movements were mainly limited by the distance between bony buttress-short process of the incus-tegmen. The

17 working space, during GG and labyrinthine FN decompression, was limited by the distance between malleus

18 head-medial epitympanic wall and malleus head-GG. Radiologic measurements were consistent with those

19 obtained during the dissections.

20 **Conclusion:** The STEA is a promising minimally invasive approach for decompression of the GG and FN's

21 labyrinthine portion. The applications of this corridor include the exploration and surgery of the medial

22 epitympanum, preserving the ossicular chain.

23

24 **Keywords:** facial nerve, geniculate ganglion, facial nerve decompression, epitympanum, endoscopic ear

25 surgery

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51

52

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

3

79   All the cadaveric dissections were performed at the Human Anatomy Institute of the University of Bologna

80   from June 2017 to February 2020. Cadavers were obtained from the cadaver donation program of the

81   Department of biomedical and neuro-motor sciences of the University of Bologna (DIBINEM), and their

82   dissection was approved for scientific purposes. This study did not require ethic committee approval. The

83   procedures used in this study adhere to the tenets of the declaration of Helsinki.

84   The STEA was performed on 10 silicon-injected and formalin fixed human cadaveric ears. Step by step

85   description of the technique and relevant measurements during each step were taken to explore the feasibility

86   and limits of the approach. Measurements were obtained by means of a small and flexible measuring strip,

87   positioned by the surgeon during the dissection, with a maximum precision of 0.5 mm. Distances inferior to 2

88   mm were measured with 0.5, 1 and 1.5 mm long microhooks. Table 1 and 2 describe the measurements

89   obtained on the specimens to assess the limits the approach.

90   The feasibility of the approach was evaluated in the different specimens in terms of visualization and proper

91   surgical working field on the anterior and posterior medial epitympanum, geniculate ganglion area, greater

92   superficial petrosal nerve, intra-petrosal tract of the first portion of the facial nerve and supra-geniculate area.

93   The proper surgical working space was assessed by 3 surgeons with different experience in endoscopic ear

94   surgery (respectively 1 year, 5 years and 12 years). The range of motion through the approach of the

95   endoscopes, surgical dissectors, bone curette, and drills were subjectively evaluated in the antero-posterior and

96   inferior-superior axis, with a 5 points Liekert scale, as reported in table 3. The possibility to complete the

97   decompression of the geniculate ganglion and the labyrinthine portion of the facial nerve, avoiding contact

98   between surgical instruments with the incudal-malleolar joint, was assessed as well. Trauma or subluxation of

99   the ossicular chain was finally evaluated.

100   *Surgical technique*

101   *Positioning and instrumentation*

102   Cadavers were positioned in supine position with a 45 degrees rotation of the head towards the contralateral

103   side. The position was the same as in routine endoscopic middle ear surgery.

104   A 3-mm-diameter and 15-cm-long 0° and 45° endoscopes, and a 4-mm-diameter and 18-mm-long 0° and 45°

105   endoscope (Karl Storz GmbH, Tuttlingen, Germany) were used and tested in all the anatomical specimens. A

106   3 CCD camera was used to record intraoperative images illustrating the approach.

107   *Suprameatal keyhole access*

108   A modified Shambaugh's incision extended from between the tragus and helix root and turning posteriorly to

109   the superior auricular sulcus was performed to expose the suprameatal area and zygomatic root (figure 1).

110   Identification of the superior wall of the external auditory canal was performed after the incision and a retractor

111   was used to expose the area of drilling. Cortical bone was exposed with periosteum dissectors.

112   A Keyhole drilling area was created in the supra-meatal region as shown in Figure 1. The tegmen tympani and

113   the superior wall of the external auditory canal were skeletonized without exposing the dura of the middle

114   fossa, until reaching the epitympanic space under microscopic or magnifying Loup view. A posterior extension

115   of the approach towards the aditus-ad-antrum and anterior antrum area may be created to increase the surgical

116   field.

117   *Endoscopic procedure*

118   A 0° - 3 mm-diameter endoscope was inserted through the supra-meatal access (Figure 1). The lateral

119   semicircular canal, the body and short process of the incus are identified and used as anatomical landmarks.

120   Then, the drilling continues under endoscopic control. The endoscope is positioned posteriorly and the surgical

121   instruments anteriorly. Thinning of the superior wall of the external auditory canal is completed in its medial

122   portion under visual control of the incus.

123   The medial portion of the posterior epitympanum is then visualized and the lateral semi-circular canal, and

124   second portion of the facial nerve can be easily detected. At this point, the endoscopic exploration with 0° and

125   45° lenses permit to explore the whole posterior medial and lateral epitympanum (figure 2). Furthermore, the

126   tympanic isthmus, long process of the incus, incudal-stapedial joint, the tensor tympani tendon and the tensor

127   fold can be visualized (figure 2). The cog limits the vision of the anterior epitympanum and can be used as a

128   landmark (if complete) to identify the geniculate ganglion area, as described in other studies[14]. Drilling out of

129   the cog permits to accede the anterior epitympanum and obtain a complete control of the anterior epitympanum,

5

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%.

157 **Results**

158 Ten anatomic dissections were carried out on 10 ears from 8 cadavers heads. The dissected side was the right

159 in 4 and the left in 6 cases. A complete exploration of the medial and lateral epitympanum was possible in

160 all the specimens. Decompression of the geniculate ganglion and first portion of the facial nerve was

161 completed and feasible without any direct trauma to the ossicular chain in 9 out of 10 ears.

162 *Endoscopic measurements*

163 Measurements obtained during anatomic dissections are reported in table 1 and 2. The diameters of the

164 external approach ranged from 15 to 20 mm (antero-posterior). The inferior-superior measures of the external

165 approach were narrower anteriorly (mean 5.4, range 4 -6 mm), compared with in the central third (mean 6.4,

166 range 6-7 mm), and the posterior third (mean 7.7, range 7-9 mm).

167 The narrowest points limiting the endoscope movements (table 3) were the distance between the bony buttress

168 (bone of fossa incudis), short process of the incus and tegmen (respectively mean 6.6, range 5.5-7 and 5.9,

169 range 4.5 – 8mm). The points limiting the working space for surgical instruments and drill (table 3) in the

170 decompression of geniculate ganglion and labyrinthine portion of facial nerve (avoiding direct trauma to the

171 ossicular chain), were the distance between malleus head the medial epitympanic wall (mean 2.8, range 1- 4

172 mm) and between the malleus head and geniculate ganglion (mean 2.6, range 1.5 – 4 mm). In particular the

173 only case of our study where a decompression of the geniculate ganglion and labyrinthine portion of the facial

174 nerve was not feasible without direct trauma to the ossicular chain, had a distance between the malleus head

175 and medial epitympanic wall of 1 mm, a dehiscent geniculate ganglion (in contact with the dura), a distance

176 between malleus head and tegmen of 1 mm and a distance between the malleus head and geniculate ganglion

177 of 1.5 mm.

178 *Radiologic measurements*

179 Radiologic measurements and their agreement with endoscopic measurements are reported in table 4.

180 Radiologic measurements of the specimens were consistent with those obtained during the anatomic dissection.

181 In particular, the distances which limit the range of movement of the endoscope and instruments overlap

182 closely with those obtained during anatomic dissection: distance between short process of the incus and tegmen

183 (mean 6.47, range 5.23 – 8.11mm), distance between malleus head the medial epitympanic wall (mean 2.84,

184 range 1.09- 4.18 mm) and between the malleus head and geniculate ganglion (mean 2.42, range 1.61 – 3.11

185 mm). The measurement of the distance between the bony buttress and tegmen, showed a significant

186 proportional bias.

187 *Complications*

188 Among the 10 cadaveric dissections we registered complications in 3 cases. As previously pointed out, in case

189 6 the narrow space did not permit to avoid direct trauma to the ossicular chain and removal of incus and malleus

190 head was necessary to complete the decompression. In the first 2 dissections, the drilling of the bone covering

191 the first portion of the facial nerve was associated with injury of the cochlea in one and of the ampulla of SSC

192 in the other.

193193

194 Discussion

195 The MCFA represents the most popular approach to the geniculate ganglion area and first portion of the facial

196 nerve. The main advantage of the MCFA is to permit a wide access to the geniculate ganglion area through

197 the tegmen tympani from an extradural plane, avoiding the interruption of the ossicular chain. Pitfalls of this

198 approach, are mainly related with its invasiveness, as it requires temporal craniotomy and temporal lobe

199 retraction. Indeed, complications of MCFA, such as postoperative seizures, intracranial haemorrhage (epidural,

200 subarachnoid and intraparenchymal), meningitis, cerebrospinal fluid leak, aphasia and hearing loss [11,15,16],

201 although rare, can be serious. Although, the MCFA to the geniculate ganglion permits to maintain the ossicular

202 chain integrity, a risk of conductive or sensorineural hearing loss, in case of ossicular chain trauma during the

203 drilling of the tegmen tympani, is possible. In addition, the anatomical variability of the middle cranial fossa

204 floor, may lead to a difficult identification of anatomical landmarks, with the possible risk of involuntary inner

205 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.

233   Our anatomic study showed the feasibility of the approach in all specimens. The external opening of the

234   approach which permitted to decompress the geniculate ganglion and the labyrinthine portion of the facial

235   nerve was small and rather constant. There was not the need to enlarge the external keyhole opening towards

236   the mastoid, both for endoscopic exploration and for gaining adequate working space for instruments in the

237   specimens. Nonetheless, it is possible to extend the external opening posteriorly towards the mastoid, as

238   desired. The narrower points of our approach for the introduction of the endoscope and epitympanic

239   exploration were the distance between the short process of the incus and/or bony buttress and the tegmen.

240   However, a complete exploration of the epitympanum was possible in all cases. The narrowest points limiting

241   the working space for the surgical instruments and drill were the distance between the malleus head and medial

242   wall of the epitympanum (Figure 4), as well as the distance between the geniculate ganglion and malleus head.

243   In cases where those distances were $\geq$ 2 mm, it was possible to safely perform the geniculate ganglion and

244   intra-labyrinthine portion decompression, avoiding any contact of the surgical instruments with the ossicular

245   chain. In cases with a predicted or observed difficult anatomy, after completing the endoscopic exploration of

246   the epitympanum, in order to increase the safety of the approach, we can recommend a preliminary incus-

247   stapes joint disarticulation, through a transcanal approach.

248   The good overlap between the measurements obtained during anatomic dissections and the radiologic

249   assessment of the specimens, are encouraging in the view of a clinical application of the approach. Indeed,

250   they can allow a preoperative prediction of feasibility of the approach for geniculate ganglion and labyrinthine

251   facial nerve decompression. Although not impacting on the feasibility of the approach, it should be taken into

252   account the disagreement found between the endoscopic and radiologic measurements of the distances between

253   first portion of the facial nerve and dura. This disagreement, as well as the proportional bias found for the

254   distance between bony buttress and tegmen, can be explained by the anatomical changes after bone drilling,

255   which can have an impact on the endoscopic measurement.

256   In our series, we encountered one case out of ten (case 6), with absent pneumatization of the zygomatic root

257   and poor pneumatization of the epitympanum, where the procedure of decompression of the geniculate

258   ganglion and first portion of the facial nerve was unfeasible, without any direct trauma or interruption of the

259   ossicular chain. However, even in this case with unfavourable anatomy, the endoscopic exploration of the

260   medial epitympanum and geniculate ganglion area was still possible, without removing the incus and malleus

261   head.

262   The complications observed in the study were caused by the lack of confidence (even for experienced

263   endoscopic ear surgeons) with the endoscopic view provided by the approach. Both cases of inner ear injury

264   occurred during facial nerve decompression in the first two approaches. Thus, cadaveric training with this

265   approach can be advocated before translating this approach into clinical practice.

266   The approach permitted a complete visual control of the anterior and posterior epitympanum with a surgical

267   point of view directed from above and from posterior to anterior (Figure 2). The visual control and the space

268   for using surgical instruments under endoscopic view was adequate through this approach both in medial and

269   lateral epitympanic areas, particularly in the posterior epitympanum area, without ossicular chain removal.

270   Thus, the privileged point of view provided by this approach permits to work surgically in the medial

271   epitympanum preserving the ossicular chain integrity. This finding extends the possible indications of the

272   STEA to the intraoperative exploration and surgical treatment of cholesteatoma in the medial epitympanum.

273   Indeed, it may be considered as a route to explore the medial epitympanum, which permits to spare both the

274   mastoid mucosa and the ossicular chain. In addition, although further research is required to define the

275   indications and limits in the clinical practice, it can be used in combination with the transcanal endoscopic

276   approach, and it may be considered as an additional endoscopic surgical route in the attempt to preserve the

277   ossicular chain during cholesteatoma surgery.

278   The main limit of the study was the limited number of dissected cadavers, which, of course, cannot cover the

279   wide variability of this anatomical area. However, the identification of critic distances limiting the feasibility

280   of the approach, along with the good overlap between radiologic and anatomic measurements, may allow a

281   preoperative selection of patients.

282282

283   Conclusions

284   The STEA is a novel and promising minimally invasive surgical approach for decompression of the

285   geniculate ganglion and labyrinthine portion of the facial nerve, which permits to preserve the ossicular

286 chain integrity. The privileged point of view provided by the approach can extend the possible applications

287 of this corridor to the endoscopic exploration and surgery of the medial epitympanum, without interrupting

288 the ossicular chain. A further study with a larger number of dissected ears is necessary to validate our results

289 within a wider spectrum of anatomical variability.

290290

291291

292292

293293

294294

295295

296296

297297

298298

299299

300300

301301

302302

303303

304304

305305

306306

307307

308308

310 **References**

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

313

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

316

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

319

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

322

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

325

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

328

329 7) Kim J, Kim J, Park S, Lee WS (2011) Use of computed tomography to predict the possibility of
330   exposure of the first genu of the facial nerve via the transmastoid approach. *Otol Neurotol*.
331   32(7):1180-1184. doi:10.1097/MAO.0b013e318229d495

332

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

336

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.

14

364   17) Lee HK, Kim IS, Lee WS (2006) New method of identifying the internal auditory canal as seen from

365   the middle cranial fossa approach. *Ann Otol Rhinol Laryngol*. 115(6):457-460.

366   doi:10.1177/000348940611500610

367

368   18) Jufas N, Bance M (2017) Endoscopically-assisted transmastoid approach to the geniculate ganglion

369   and labyrinthine facial nerve. J Otolaryngol Head Neck Surg. 46(1):53.

370

371

372

373

374

375

376

377

378

379

380

381

382

383

384

385

386   **Figure Legends**

387

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

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

395395

396   **Fig. 2** Endoscopic exploration of the epitympanum

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

401401

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

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

407407

408   **Fig. 4** Radiological measures and endoscopic view left ear.

409   A: CT scan, coronal view posterior to geniculate ganglion. B: CT scan, axial view. C: endoscopic view 3mm-
410   0° endoscope. aSCC: ampulla of superior semicircular canal. iac: internal auditory canal; ILiac: labyrinthine
411   portion of facial nerve close to the internal auditory canal; ILpg: labyrinthine portion of facial nerve peri-
412   geniculate ganglion (close to geniculate ganglion); 2°FNpg: second portion of facial nerve perigeniculate
413   ganglion (close to geniculate ganglion); mh: malleus head. White lines on the left and black lines on the right
414   (corresponding endoscopic and radiologic measurements): a: malleus head – tegmen; b: malleus head – medial
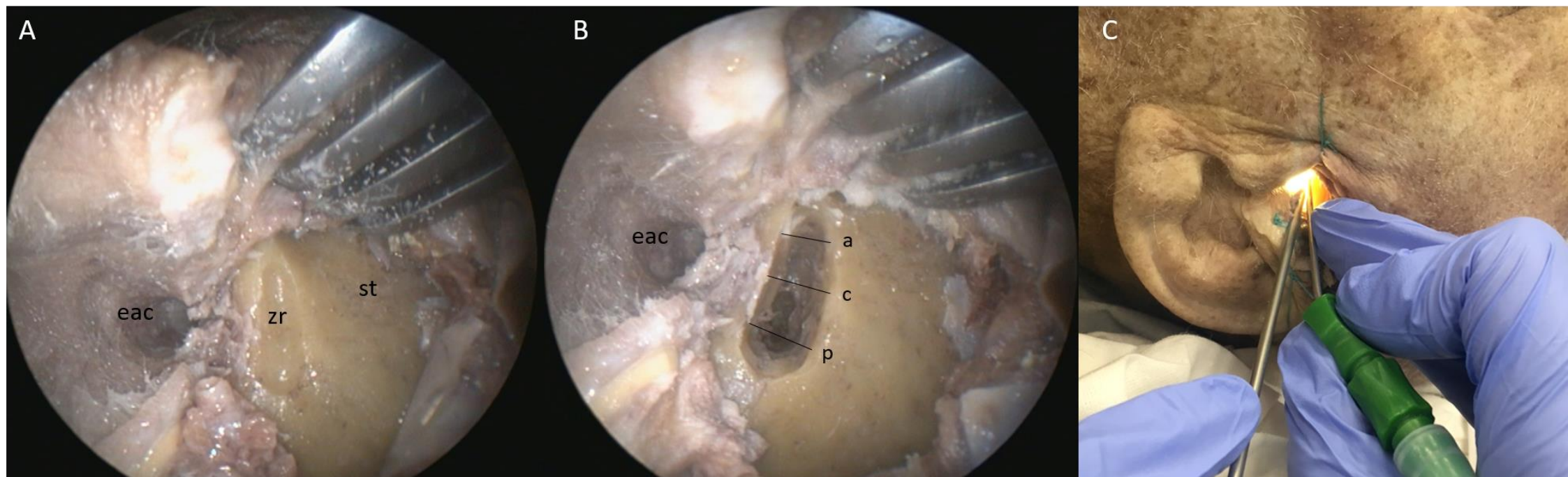415   wall of epitympanum, c: malleus head; aSSC: ampulla of superior semicircular canal.
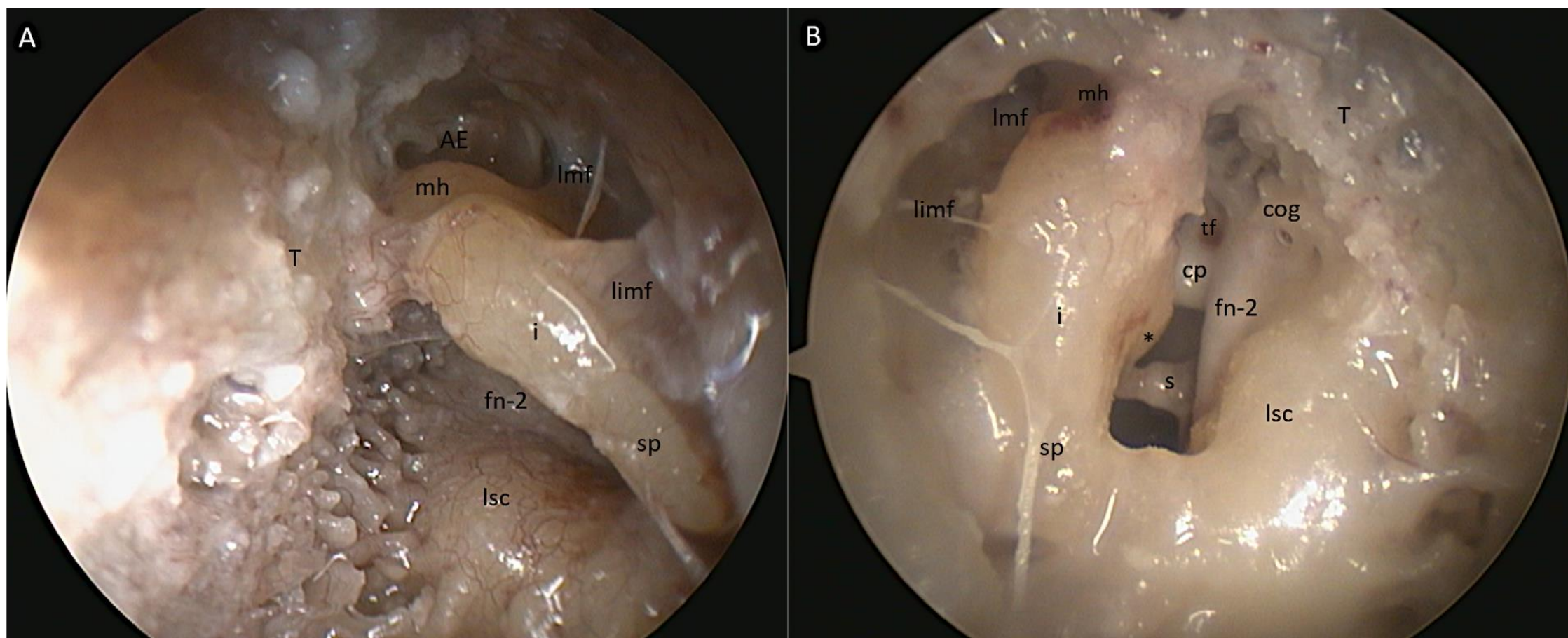
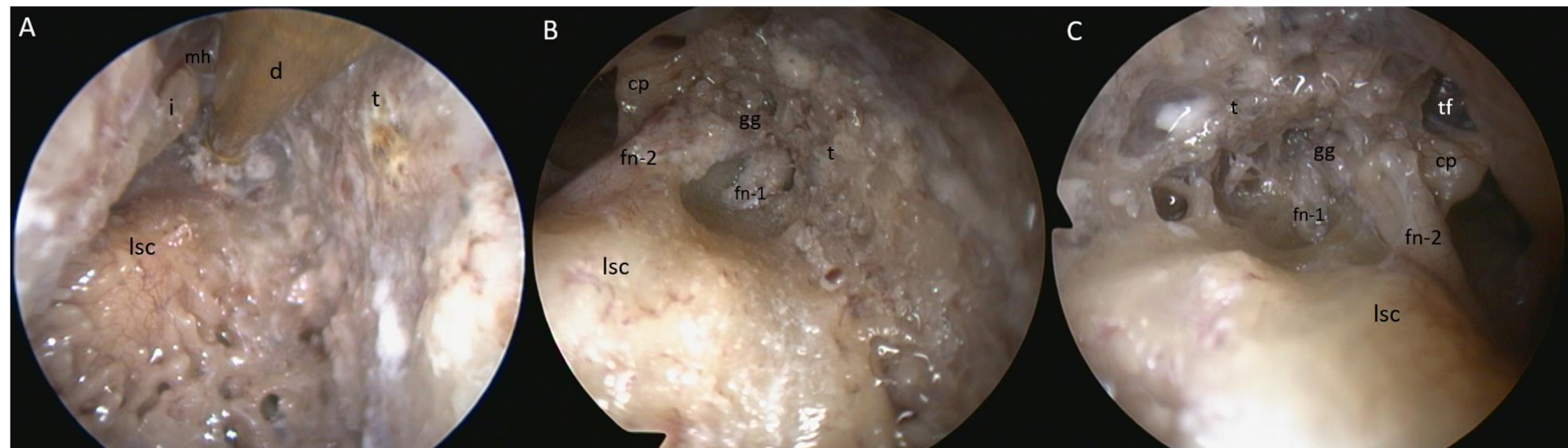416416

417417

418418

419419

Figure 1

Figure 2

Figure 3

Figure 4
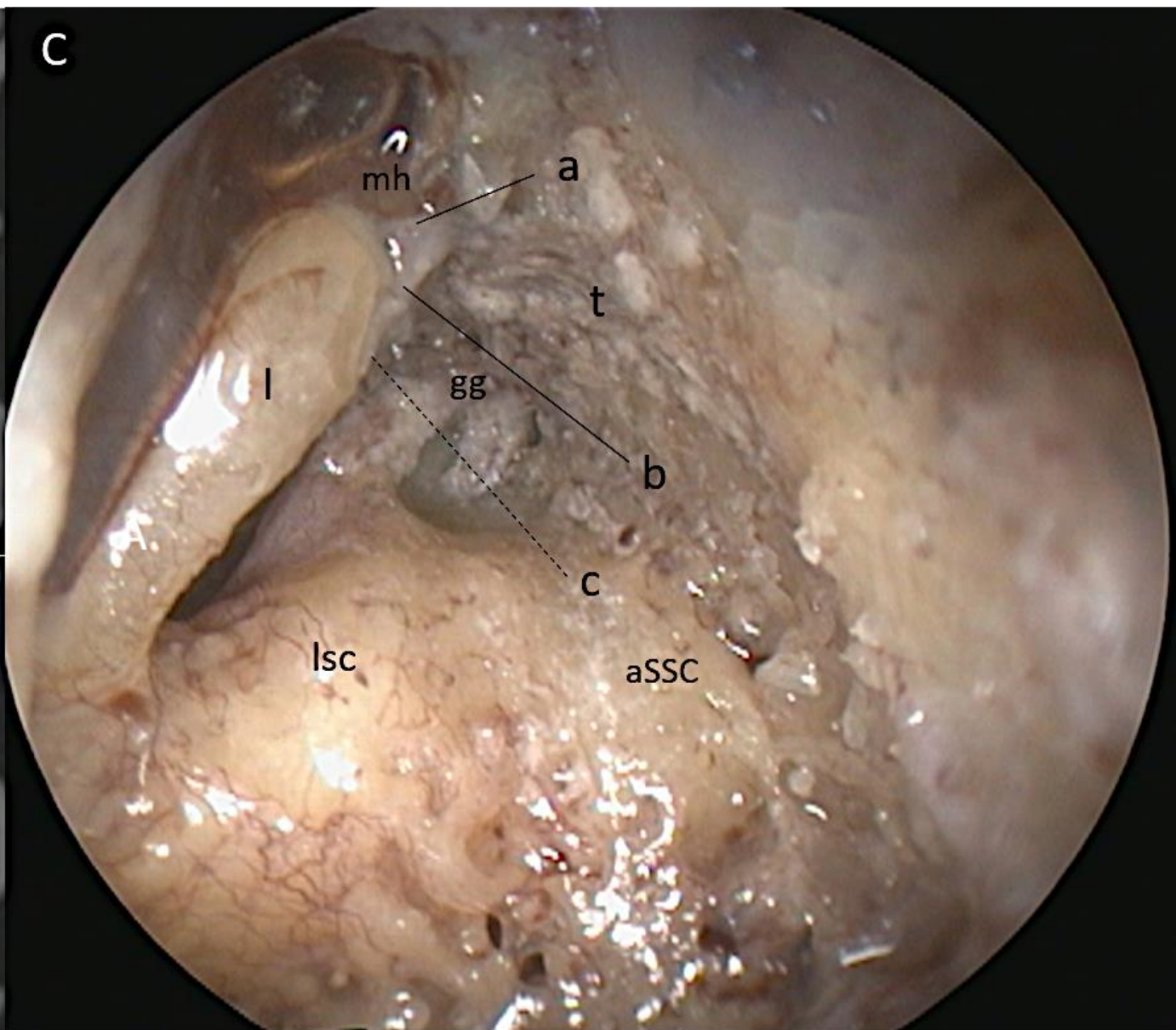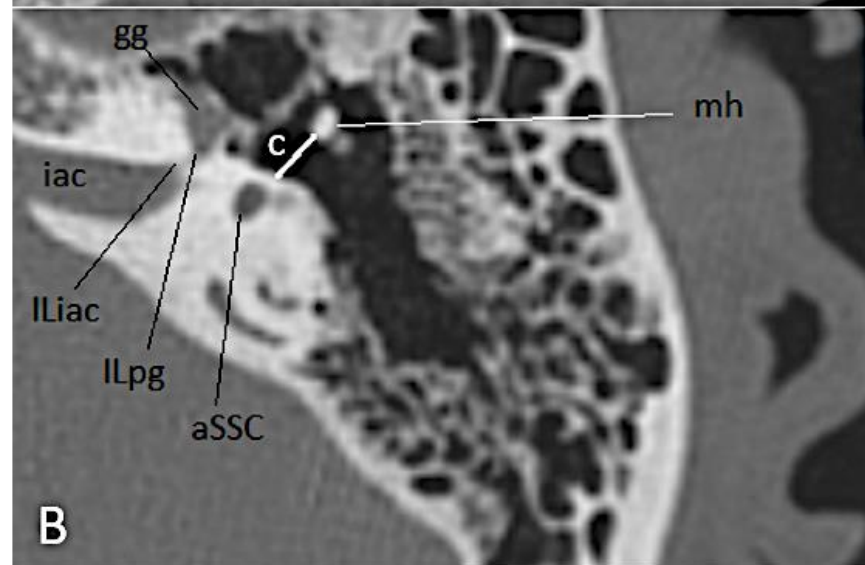
Table 1

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