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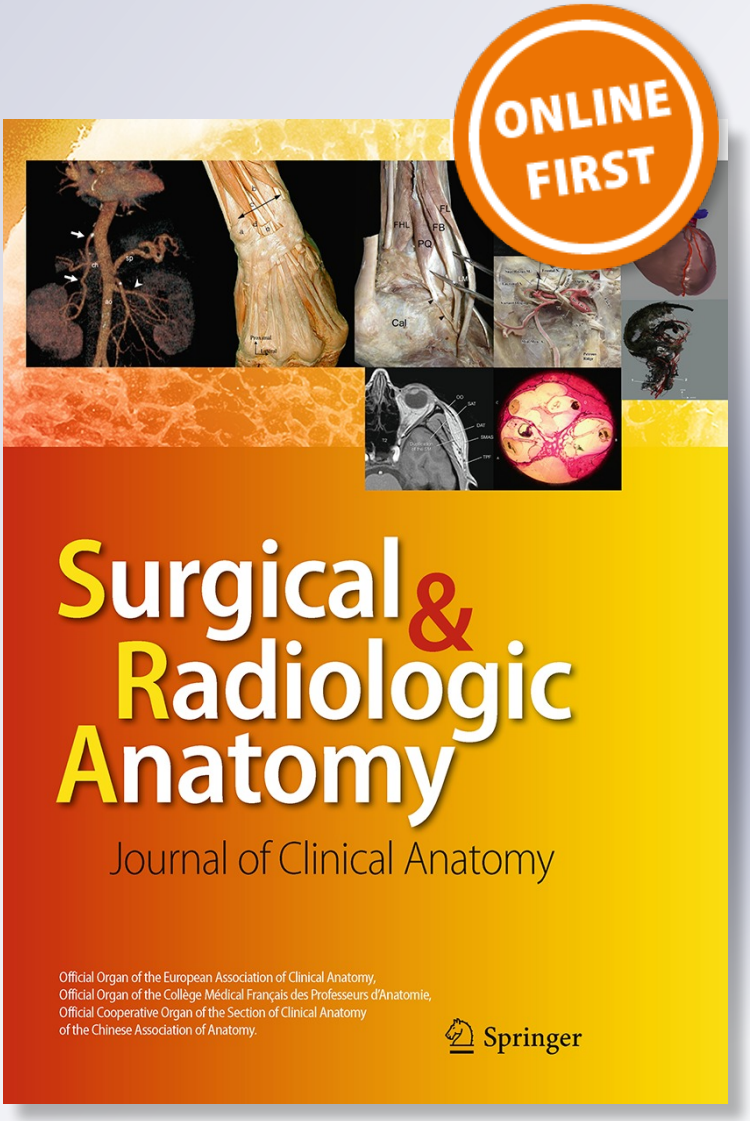
Surgical and Radiologic Anatomy

ISSN 0930-1038

Surg Radiol Anat
DOI 10.1007/s00276-016-1662-5



Springer

Surg Radiol Anat
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ORIGINAL ARTICLE

Round window chamber and fustis: endoscopic anatomy and surgical implications

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Received: 14 September 2015 / Accepted: 29 February 2016

Abstract The round window region is of critical importance in the anatomy of the middle ear. The aim of this paper is to describe its anatomy from an endoscopic point of view, emphasizing structures that have important surgical implications, in particular the fustis and the subcochlear canaliculus. The fustis, a smooth bony structure that forms the floor of the round window region, is a constant and important structure. It seems to indicate the round window membrane and the correct position of scala tympani. A structure connecting the round window region to the petrous apex, named the subcochlear canaliculus, is also described. A retrospective review of video recordings of endoscopic dissection and surgical procedures, carried out between June 2014 and February 2015, was conducted across two Tertiary university referral centers. A total of 42 dissections were analyzed in the study. We observed the fustis in all the cases and we identify two different anatomical conformations. The subcochlear canaliculus was found in 81.0 %, with a pneumatization direct to the petrous apex in 47.7 %. Conformation and limits of the round window niche may influence the surgical view of the round window membrane. Endoscopic approaches allow a very detailed view, which enables a comprehensive exploration of the round window region. Accurate knowledge of the anatomical relationships of this region has important advantages during middle ear surgery.

Keywords Round window region · Subcochlear canaliculus · Fustis · Endoscopic anatomy · Middle ear

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Introduction

The round window chamber is a three-dimensional space lying between the round window niche and round window membrane [7]. Between the fustis and the finiculus a subcochlear canaliculus is often seen, which is a tunnel that connects the round window chamber with the petrous apex via a series of pneumatized cells. Three different types of subcochlear canaliculus have been described: type A has a large tunnel to the petrous apex detectable endoscopically; type B has a small tunnel present, with a connection to the petrous apex not detectable endoscopically; type C has no connection between the round window chamber and the petrous apex [4].

The fustis (from latin, "club") is a smooth bony structure, which forms the floor of the round window chamber and seems to indicate the entrance to the round window niche. The structure links the styloid proeminence with the basal turn of the cochlea.

During the last 10 years, the knowledge of the middle ear anatomy, and specifically the retrotympanum, has been significantly improved with the help of the endoscopic approach [3]. The traditional microscopic approach rarely allows for clear visualization of the retrotympanic spaces. The primary advantage of the endoscope lies in its capacity to magnify and visualize these and other areas despite

Published online: 14 March 2016

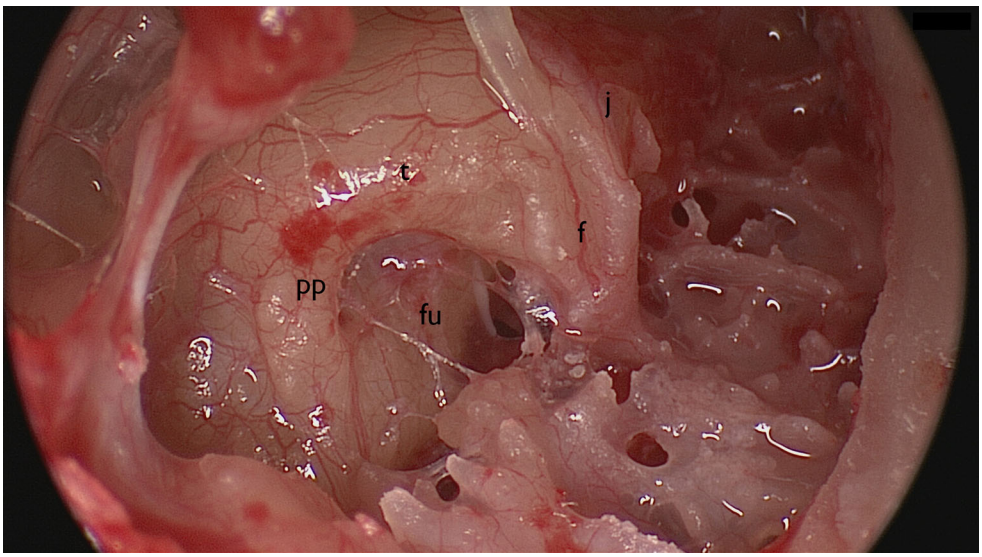

Fig. 1 Right ear. Endoscopic anatomy of inferior retrotympanum. *fu* fustis, *t* tegmen, *pp* posterior pillar, *f* finiculus, *j* jacobson's nerve

lacking line of sight. This is due to an objective lens that can be angled and introduced into the middle ear.

The round window niche has been described as an area lying between the subiculum posteriorly and slightly superior and the finiculus anteriorly and slightly inferior. It is triangular in shape, bounded by the posterior pillar, tegmen, and anterior pillar, with the round window membrane at its apex [6]. The subiculum (from latin, "support") extends from the posterior pillar towards the styloid proeminence, limiting the sinus tympani inferiorly. The finiculus (from latin, "borderline") extends from the anterior pillar toward the jugular dome, separating the retrotympanum from the hypotympanum. It was initially called sustentaculum promontori by Proctor [7], as it was thought to always contain the inferior tympanic artery.

The aim of this study is to analyze a relationship between the fustis and the scala tympani and between the subcochlear canaliculus and the petrous apex. Understanding these relationships is of importance during middle ear surgery, particularly surgery involving the round window region, when unfavorable anatomy is present.

Materials and methods

A retrospective review of video recordings of 42 endoscopic dissection and surgical procedures, carried out between June 2014 and February 2015, was conducted across two Tertiary university referral centers. Cadaveric dissections of the middle ear performed specifically to investigate the round window region, as well as intraoperative surgical dissections for transcochlear vestibular schwannoma removal, were included in the study. All dissections were performed using 0°, 30°, and 45° rigid Hopkins rod telescopes with a 3 mm outside diameter, 15 cm length, (Karl Storz, Tuttlingen, Germany). Surgical dissections also utilized diamond burrs and a Piezosurgery device (Mectron, Carasco, Italy). A three-CCD camera system and high-resolution monitor were used for all procedures, which were also recorded in digital format for archival. In all procedures, the external auditory canal (EAC) skin was incised creating an inferiorly based tympanomeatal flap, which was freed from the malleus handle, in order to facilitate access. The tympanic cavity was fully visualized and a transcanal endoscopic approach to the round window region was performed, recording relevant anatomical features (Fig. 1). The primary aim of this study was to delineate the anatomical variants of the fustis in relation to the round window chamber, including the direction of the fustis from the styloid proeminence to the round window membrane. If a procident tegmen was present, limited curettage or drilling of the tegmen was performed to expose the round window membrane. If mucosal folds were present, they were removed with sharp dissection. Both of these aspects of the dissection were noted. After initial endoscopic visualization, the round window membrane was removed to reveal the scala tympani (Fig. 2). Further curettage or drilling of the tegmen as well as promontory allowed for a complete understanding of the relationship of the fustis and scala tympani in each ear (Fig. 3). Other aspects studied and recorded included the anatomical limits of round window niche formed by the

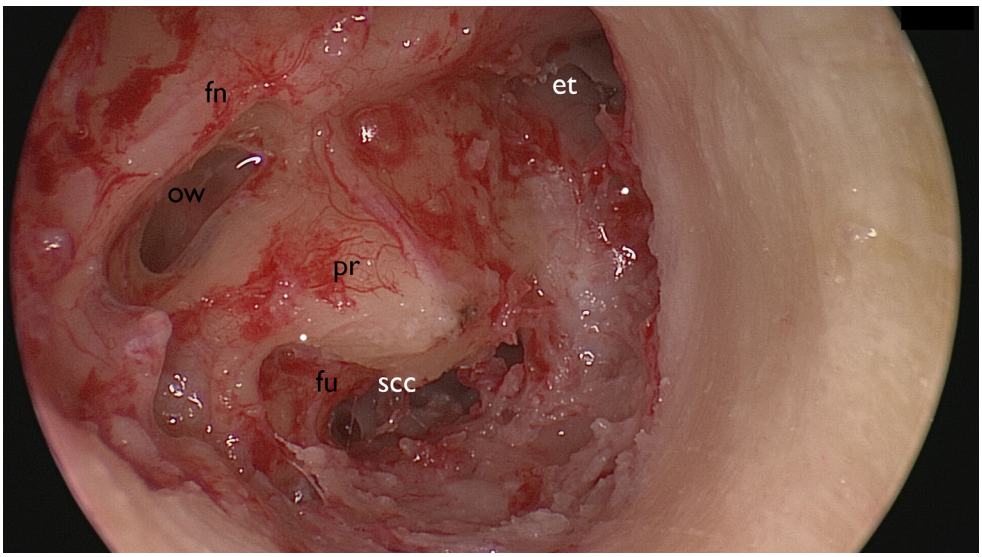

Fig. 2 Right ear. Endoscopic anatomy of the retrotympanum during dissection for acustic neuroma surgery. *fu* fustis, *fn* facial nerve, *ow* oval window, *pr* promontory, *scc* subcochlear canaliculus, *et* Eustachian tube

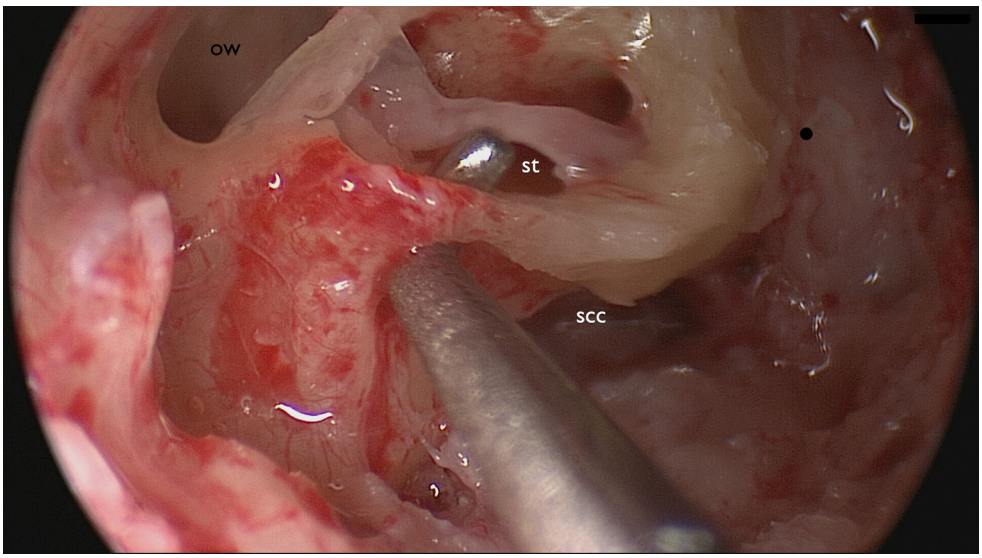

Fig. 3 Right ear. Endoscopic dissection during surgery, after drilling the promontory. *ow* oval window, *st* scala tympani, *scc* subcochlear canaliculus

tegmen, finiculus, and subiculum, as well as the presence and type of subcochlear canaliculus.

Results

A total of 42 dissections, 37 cadaveric, and 5 surgical for endoscopic transcochlear acoustic neuroma excision were included. There were a total of 19 left side and 23 right side ears.

Round window niche

In examining the anatomical limits of the round window niche, the following results were noted:

- finiculus was complete (type A) in 39/42 (92.9 %), incomplete (type B) in 1/42 (2.4 %), and absent (type C) in 2/42 ears (4.8 %);
- subiculum was complete (type A) in all 42/42 ears, with no incomplete (type B) or absent (type C) variations noted;

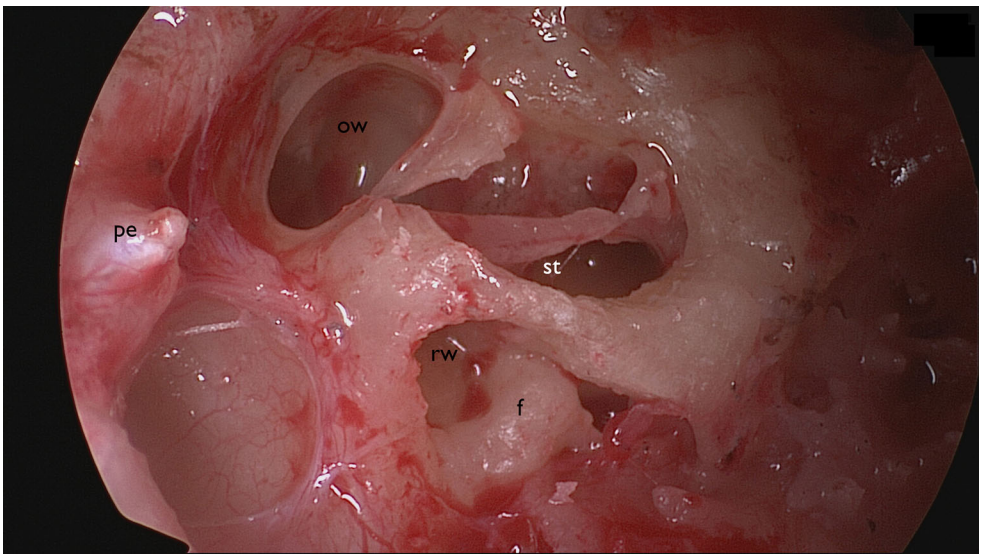

Fig. 4 Right ear. Endoscopic view of fustis type B. *ow* oval window, *st* scala tympani, *fu* fustis, *pe* pyramidal eminence, *rw* round window

– in 4/42 (9.5 %) a procident tegmen covering the round window membrane was found.

Round window chamber

In examining the anatomical features of the round window chamber, the following results were identified:

- in 34/42 (81.0 %) of ears, a subcochlear canaliculus was found between the fustis and the finiculus
  - in 20/42 (47.7 %) of ears this was a deep tunnel visualized to the petrous apex endoscopically (type A)
  - in 14/42 (33.3 %) of ears this was a small tunnel incompletely visualized endoscopically (type B);
- in the remaining 8/42 (19.0 %) ears, no connection between the round window chamber and petrous apex was observed (type C);

Relationship of fustis and round window membrane

In all cases, the fustis was observed traversing the round window chamber as a smooth bony structure, arising from the styloid proeminence posteriorly and extending lateral to medial towards the round window membrane. In our observations, two unique anatomical conformations of fustis were identified: type A (Figs. 2, 3) and type B (Figs. 4, 5).

- Type A (30/42, 71.4 %) the fustis coursed in an oblique direction from the styloid proeminence posteriorly and inferiorly to the round window niche anteriorly and superiorly, pointing like a finger to the round window membrane; after cutting the membrane we could identify the scala tympani.
- Type B (12/42, 28.6 %) the fustis was arising from the styloid proeminence posteriorly and passes under the round window membrane anteriorly, in particular the antero-superior limit of the fustis seemed to delimit the anterior edge of the round window membrane.

Relationship of fustis and scala tympani

Following curettage or drilling of the tegmen and promontory in order to fully visualize the round window membrane and subsequently the basal turn of the cochlea, scala tympani and vestibule, we observed the anatomical relationship between the fustis and the scala tympani.

- in a type A fustis, the direction of the fustis leads to the scala tympani;
- in a type B fustis, the anterosuperior limit of the fustis lies just under the scala tympani and represents the floor of the scala tympani.

Discussion

Although some authors have studied the anatomy of the inferior retrotympanum [1], the region has been largely neglected in the literature [8, 9]. This is likely due to an inability to completely visualize the region without endoscopes. Embyrologically the retrotympanum and hypotympanum arise from an endothelium-lined fluid pouch, the

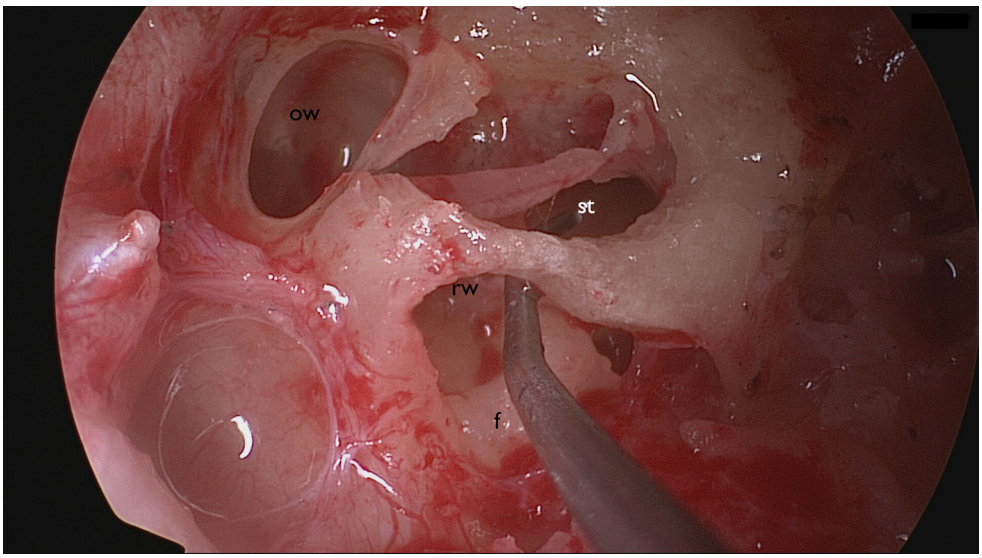

Fig. 5 Right ear. The tool shows the scala tympani. *ow* oval window, *st* scala tympani, *fu* fustis, *rw* round window

saccus posticus, that extends toward middle ear cleft from the tubo-tympanic recess [2, 5]. The retrotympanum was described for the first time by Steinbrugge H [10] at the end of the nineteenth century. During the twentieth century, Proctor [6, 7] improved the knowledge of the retrotympanum anatomy, based on temporal bone dissections. Proctor defined a bony structure, representing the floor of the retrotympanic region that he called the area concamerata. Although the pars media of the area concamerata (Proctor's "fustis"), a smooth bony column mainly forming the floor of the round window niche, could be easily recorded in some of the ears within this study. During this study, attention was paid to the inferior retrotympanum and in particular the structures which form the round window chamber and are contained within it. In comparison with previous data, the distribution of types of subiculum and finiculus conformed with previously demonstrated data. This study also reviewed the presence of the subcochlear canaliculus, which has previously been subtyped and analyzed. The proportion of type C subcochlear canaliculi remained constant respect the previous study, but there appeared to be a distribution favoring type B. The classification of a subcochlear canaliculus relies on radiological correlation to truly differentiate a type A from type B (Figs. 6, 7, 8). From this preliminary work, the fustis may represent a landmark of the scala tympani. Two types of orientation of the fustis related to the scala tympani were shown. Type A is when the fustis presented an oblique orientation from the styloid proeminence to the round window membrane and following the direction of the fustis from posterior to anterior allowed an accurate identification of the position and orientation of the scala tympani

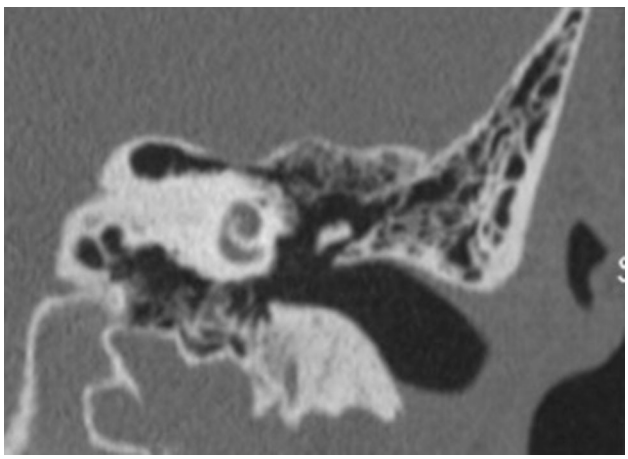

Fig. 6 Subcochlear canaliculus type A

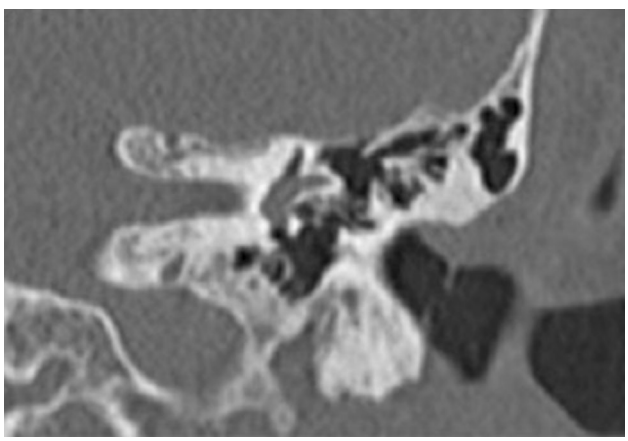

Fig. 7 Subcochlear canaliculus type B

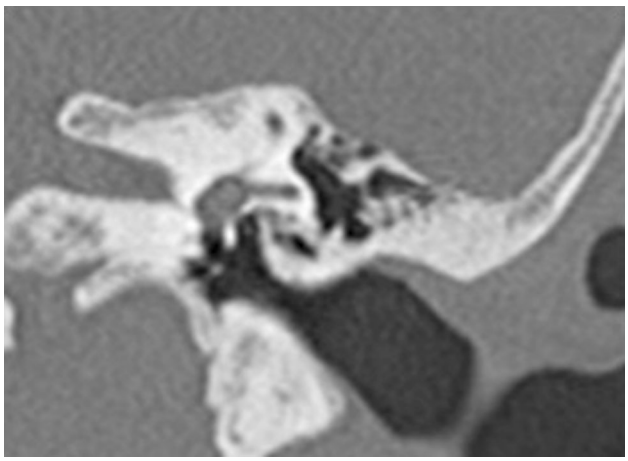

Fig. 8 Subcochlear canaliculus type C

(Fig. 9). Type B was when the anterior portion of the fustis was laying just inferiorly with respect the round window membrane, forming the floor of the scala tympani (Fig. 10). In this study round window region anatomy was analyzed, showing that fustis appears as a well-defined and constant anatomical structure, so it could be considered a good landmark to correctly identify the round window niche. Following the orientation of the smooth bone from posterior to anterior appears to be a reliable indicator of the scala tympani floor. These anatomical findings are very important for clinical applications during middle ear surgery in several conditions. First of all, when a tympanic cavity cholestetoma, in particular in children, has an infiltrative matrix and is localized into these areas, passing through the subcochlear canaliculus. In this case, if a well-developed subcochlear canaliculus is present (type A), it is possible to have a residual disease that, after several time, could evolve into a petrous apex cholesteatoma, making difficult the management and more extensive the revision surgery. The second condition can be showed during cochlear implant surgery. When unfavorable intraoperative conditions make difficult to correctly identify the round window niche and the scala tympani, for example in case of malformed ears or when an important cochlear ossification is found, the fustis is a constant landmark that can help the surgeon to find the correct site for the insertion of the array. In any case, when the round window region is covered and not immediately accessed, the presence of constant and well-defined landmarks, as the fustis, can be very useful when a middle ear surgery is performed.

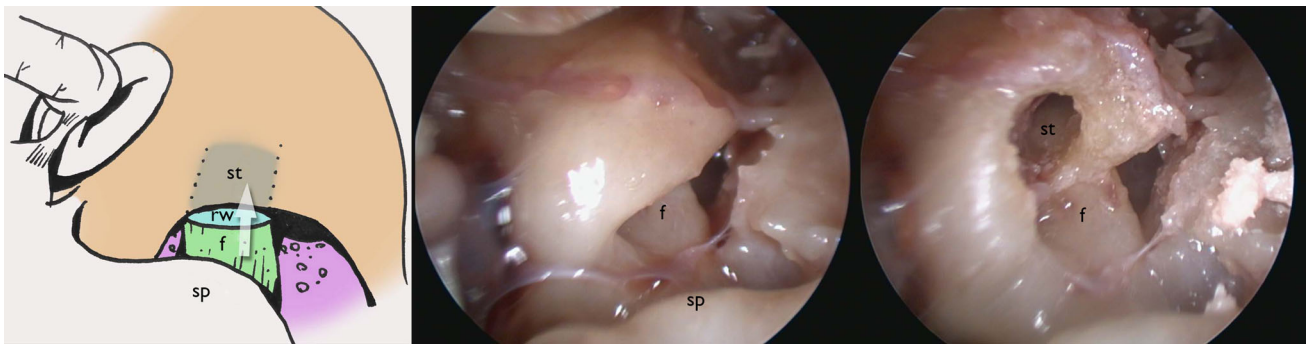

Fig. 9 Type A fustis. *f* fustis, *sp* styloid proeminence, *st* scala tympani, *rw* round window

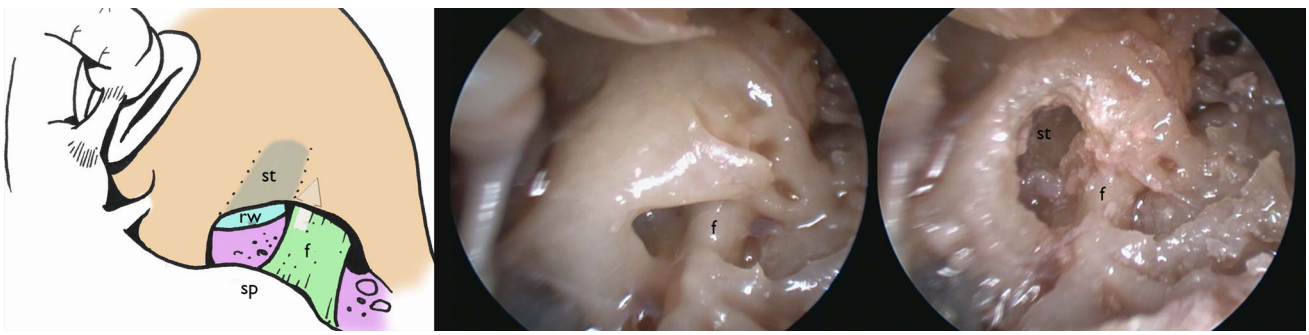

Fig. 10 Type B fustis. *f* fustis, *sp* styloid proeminence, *st* scala tympani, *rw* round window

Conclusions

The endoscopic approach allows a better understanding of the inferior retrotympanum and the round window chamber. In this cohort of ears studied, the fustis is a constant structure which points toward the round window niche and has a reliable relationship to the scala tympani. Although further study of the fustis and the region it is contained within is needed, it can be considered a constant landmark, particularly when it is important to know the location of the round window membrane and structures beyond it such as the scala tympani.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Garcia PJ, Tamega OJ, Soares JC, Piffer CR, Zorzetto NL (1982) Contribution to the study of the styloid prominence in the posterior tympanic cavity. Anat Anz 151:247–254
2. Grevellec A, Tucker AS (2010) The pharyngeal pouches and clefts: development, evolution, structure and derivatives. Semin Cell Dev Biol 21:325–332
3. Marchioni D, Alicandri-Ciufelli M, Piccinini A, Genovese E, Presutti L (2010) Inferior retrotympanum revisited: an endoscopic anatomic study. Laryngoscope 120:1880–1888
4. Marchioni D, Alicandri-Ciufelli M, Pothier DD, Rubini A, Presutti L (2015) The round window region and contiguous areas: endoscopic anatomy and surgical implications. Eur Arch Otorhinolaryngol 272:1103–1112
5. O'Rahilly R, Müller F (2010) Developmental stages in human embryos: revised and new measurements. Cells Tissues Organs 192:73–84
6. Proctor B (1969) Surgical anatomy of the posterior tympanum. Ann Otol Rhinol Laryngol 78:1026–1040
7. Proctor B, Bollobas B, Niparko JK (1986) Anatomy of the round window niche. Ann Otol Rhinol Laryngol 95:444–446
8. Savić D, Djerić D (1985) Anatomical variations and relations in the medial wall of the bony portion of the eustachian tube. Acta Otolaryngol 99:551–556
9. Savic D, Djeric D (1987) Surgical anatomy of the hypotympanum. J Laryngol Otol 101:419–425
10. Steinbrugge H (1889) On sinus tympani. Arch Otolaryngol 8:53–57