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Facial Sinus Endoscopic Evaluation, Radiologic Assessment, and Classification

Matteo Alicandri-Ciufelli, MD, FEBORL-HNS; Matteo Fermi, MD; Marco Bonali, MD;
Livio Presutti, MD; Daniele Marchioni, MD; Alessandra Todeschini, MD; Lukas Aschuetz, MD

Objectives: To describe facial sinus anatomy from an endoscopic perspective and present a radiologic classification.

Methods: Facial sinus was studied by endoscopy and high-resolution computed tomography (HRCT) scan in 39 temporal bones that underwent exclusive transcanal endoscopic approach. A radiomorphologic classification based on the relationship between the facial sinus and the mastoid portion of the facial nerve is created as follows. In type A facial sinus, the pneumatization of the facial sinus did not extend medially or posteriorly to the mastoid portion of the facial nerve. In type B facial sinus, the pneumatization extended posteriorly to the mastoid portion of the facial nerve. In type C facial sinus, the pneumatization extended posteriorly and medially to the mastoid portion of the facial nerve.

Results: In all the specimens that underwent HRCT ($n = 31$), facial sinus could be identified, and its depth classified, in relation to the facial nerve. In this group, 58% type A, 29% type B, and 13% type C facial sinuses were identified. In all the specimens ($n = 39$), the facial sinus could be assessed by means of an exclusive endoscopic transcanal approach, and anatomical variants of the chordiculus, previously known as chordal ridge, could be described: ridge (39%), bridge (18%), incomplete (15%), and absent (28%).

Conclusion: Endoscopic exploration of the retrotympanum guarantees a very good exposure of the facial sinus, allowing detailed anatomic descriptions of its conformation and relationships with other structures. Improvement in our knowledge of its anatomy might decrease the possibility of residual disease during cholesteatoma surgery. Angled endoscopes (e.g. 45°, 70°) can guarantee a better view of the facial sinus.

Key Words: Facial sinus, lateral tympanic sinus, transcanal endoscopic approach, retrotympanum, middle ear, *chordiculus*, radiologic classification.

Level of Evidence: NA.

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INTRODUCTION

In the recent literature, the present authors have already studied the endoscopic and radiologic anatomy of the retrotympanum,[1] describing the variations in shape and relationship of the sinus tympani,[2,3] the pyramidal eminence with the subpyramidal space,[4] and the round window niche.[5]

However, until now no studies have focused on the endoscopic anatomy of the facial sinus (FS) and its relationship with surrounding structures.

The FS was probably described for the first time in 1888 by Sappey,[6] and for this reason is also known as the *suprapyramidal fossa of Sappey*. The FS is an area superolateral to the pyramidal eminence bounded by the posterior edge of the bony annulus laterally, the fossa incudis superiorly, the third tract of the facial nerve (FN) medially, and an inconstant bony ridge inferiorly. This ridge is called the *chordal ridge*; it runs from the roof of the pyramidal eminence toward the chordal eminence, where the chorda tympani enters the tympanic cavity. This latter anatomical landmark divides the FS from the lateral tympanic sinus (LTS), also known as the *fossa of Grivot*,[7] placed inferiorly compared to FS. Since then, the FS has been described from a microscopic point of view mainly because it represents the route used in posterior tympanotomy that allows access to the tympanic cavity and the round window area (Fig. 1).

In the last decade, there has been a growing interest regarding the transcanal endoscopic ear surgery (TEES), a technique that allows for the management of middle ear disease, such as cholesteatoma, with no external incisions, minimal morbidity for patient, short hospital stay, and low complications rate.[8] As mentioned above, the endoscopic view improves visualization of the retrotympanum as well as its recesses, such as the posterior tympanic sinus (PTS), sinus tympani (ST), and sinus subtympanicus.[1] However, an endoscopic description and

From the Otolaryngology–Head and Neck Surgery Department, University Hospital of Modena (M.A-C., M.F., M.B., L.P.), Modena; the Otolaryngology–Head and Neck Surgery Department, University Hospital of Verona (D.M.), Verona; the Neurosurgery Department (M.A-C.); the Neuroradiology Department (A.T.), New Civil Hospital Sant'Agostino-Estense, Baggiovara, Italy; and the Department of Otorhinolaryngology, Head and Neck Surgery, Inselspital, University Hospital and University of Bern (L.A.), Bern, Switzerland.

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Send correspondence to Matteo Fermi, MD, Otolaryngology–Head and Neck Surgery Department, University Hospital of Modena, Via del Pozzo 71, 41100 Modena, Italy. E-mail: matteo.fermi.med@gmail.com

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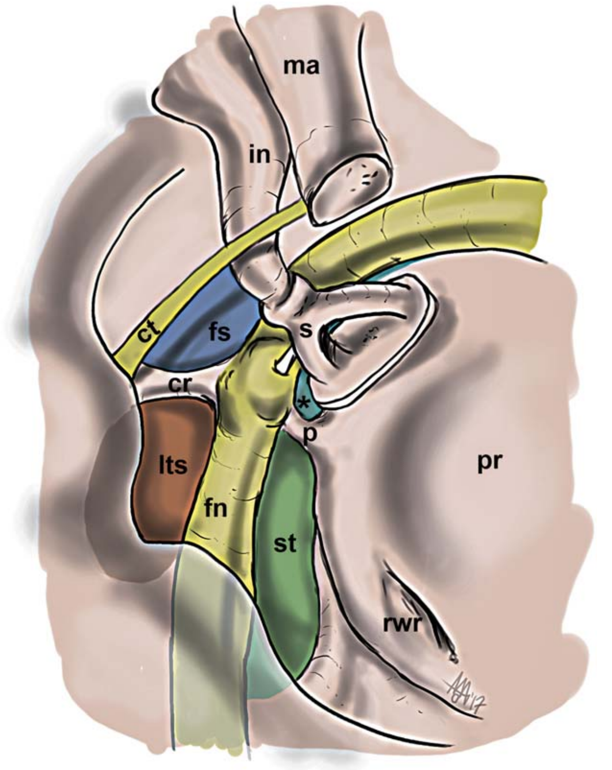

Fig. 1. Right ear. Drawing representing the medial and lateral spaces of the retrotympanum. Anatomic boundaries of the fs are here clarified. Note that the chordal ridge, the bony crest that divides the fs from the lts, has been renamed as chordiculus by present authors. *Posterior sinus. cr = *chordiculus*; ct = chorda tympani; fn = facial nerve; fs = facial sinus; in = incus; lts = lateral tympanic sinus; ma = malleus; p = ponticulus; pr = promontory; rwr = round window region; s = stapes; st = sinus tympani. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

analysis of the FS and its topographic relationships are still lacking in the literature.

The aim of our study is to analyze and revisit the morphology and anatomic variations of the facial sinus from an endoscopic and radiologic point of view, trying to produce an easy and fast classification, such as the one already proposed for the ST.[3] The present authors consider that these descriptions could be important for ear surgeons because a thorough assessment of this space could have consequences on clinical and surgical practice.

MATERIALS AND METHODS

From January 2017 to July 2017, 39 temporal bones were prospectively included in our study. Of these, 31 specimens previously underwent a high-resolution computed tomography (HRCT). Axial projections were obtained with sequential 1.0-mm slices; scanning was performed from the arcuate eminence to the jugular fossa. The variation in depth of the FS and ST areas were assessed, analyzing the posterior and medial extension of the medial boundary of the FS and ST with respect to the mastoid portion of the FN. A radiomorphologic classification of the FS was created (Figs. 2–3) (Table I) in a similar fashion already introduced for ST.[2,3] Thus, the depth of each FS was classified based on the relationship to facial nerve.

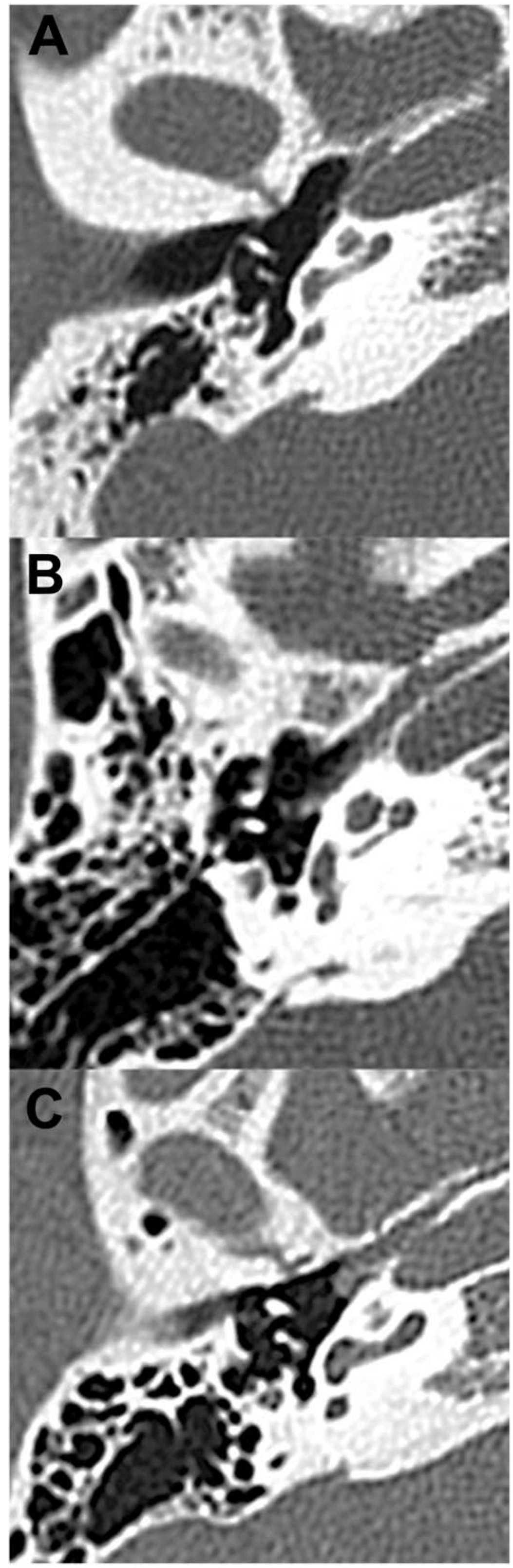

Fig. 2. Radiomorphologic evaluation of the depth and extension of the fs in relationship to the mastoid portion of the facial nerve (based on axial computed tomography scan, right ear). (A) Small fs. (B) Deep fs with posterior extension. (C) Very deep fs with medial and posterior extension. Black arrow indicates the third portion of the facial nerve. fs = facial sinus.

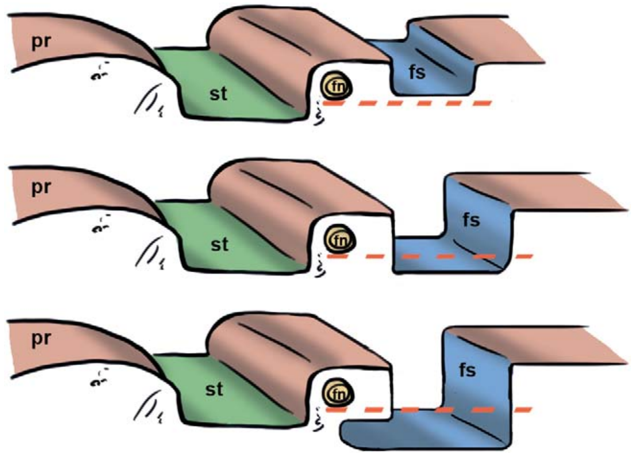

Fig. 3. Classification of the depth of the fs. (A) Fs type A: Small fs without medial and posterior extension with respect to the mastoid portion of the fn. (B) Fs type B: fs with posterior extension and without medial extension with respect to the mastoid portion of the fn. (C) Fs type C: fs with medial and posterior extension with respect to the mastoid portion of the fn. fn = facial nerve; fs = facial sinus; pr = promontory; st = sinus tympani. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Later, all of the specimens (n = 39) underwent endoscopic dissection by means of an exclusive transcanal approach.

The equipment used during dissection consisted of 0° and 45° rigid Hopkins endoscope (3-mm diameter, 15-cm length) and a 70° rigid Hopkins endoscope (4-mm diameter, 15-cm length) (Karl Storz, Tuttlingen, Germany). A three-chip high-resolution monitor and camera (Karl Storz) were used for all of the procedures. A set of angled instruments was used for all the surgical steps. The transcanal approach consisted of elevation of the tympanomeatal flap to access the middle ear cleft, and exploration of the superior retrotympanum was performed as already described in earlier papers.[3] The exploration of the recesses of the superior retrotympanum required prior cleaning and removal of mucosal folds with angled instruments. The anatomy was documented photographically and reviewed by the authors.

The data were summarized in appropriate database. Descriptive statistics were performed with Microsoft Excel, 15.33 version (Microsoft Corporation, Redmond, WA).

RESULTS

Radiologic Findings

In all the specimens (n = 31 temporal bones) that had a HRCT scan, radiologic conformation of the FS and the ST could be classified by evaluating the relationship with the mastoid portion of the facial nerve in CT scan-axial plane.

Based on our classification of the FS, it was found that 18 of 31 (58%) temporal bones had a radiologic morphology type A; nine of 31 (29%) had a radiologic morphology type B; and four of 31 (13%) had a radiological morphology type C (Figs. 2–3).

Regarding the ST, the radiologic morphology was assessed by the criteria already described in literature.[2] It was found that 14 of 31 (45%) temporal bones had a radiologic morphology type A; 15 of 31 (48%) had a radiologic morphology type B; and two of 31 (7%) had a radiologic morphology type C.

A correspondence of depth (e.g., FS type A and ST type A) in the radiologic morphology of the FS and ST was found in 15 of 31 (48%) specimens.

TABLE I.
Radiomorphologic classification of facial sinus

	Facial Sinus	Pneumatization of Facial Sinus
Type A	Small	Not beyond the mastoid tract of facial nerve
Type B	Deep	Posteriorly to mastoid tract of facial nerve
Type C	Very deep	Posteriorly and medially to the mastoid tract of facial nerve

Endoscopic Findings

In all the specimens (n = 39 temporal bones), the FS could be assessed by means of an exclusive transcanal approach. In all the cases, 0° and 45° scopes were used, whereas we only could use the 70° scope in 33 cases due to its wider outer diameter (4 mm), which could not be handled in cases of narrow EAC. In 34 of 39 (87%) specimens, the FS appeared as pneumatized and well delimited.

In only two of 39 (5%) specimens, the FS could be entirely explored with a 0° scope, whereas the percentage rose up to 51% (20 of 39) with a 45° scope. Even if only 33 specimens were studied with the 70° lens, the FS was completely assessed in 27 of 33 (81%) temporal bones (Fig. 4).

In 28 of 39 (72%) specimens, a structure arising from the roof of the pyramidal eminence and connected to the chordal eminence was found located at the posterior edge of the bony annulus and corresponding to the entrance of the chorda tympani into the middle ear cavity. This structure represented the limit between the LTS and the FS, as mentioned. Former authors named that structure the *chordal ridge*.[6,7] Actually, some variations in morphology of the chordal ridge were noticed. In 15 of 39 (39%) cases, it was like a ridge of bone; however, in seven of 39 (18%) cases, it was bridge-shaped, in six of 39 (15%) cases it was incomplete, and in 11 of 39 (28%) cases it was absent (Fig. 5). Due to these results concerning anatomic variability, in particular the presence of a significant percentage of bridge-shaped chordal ridge, the present authors deemed it appropriate to rename this the *chordiculus*. This denomination would also help develop a more systematic nomenclature for retrotympanic structures.

The FS was seen to have two kinds of anatomic conformation:

- Classic shape (15 of 39, 39%): the sinus is located between the lateral semicircular canal and the *chordiculus*, positioned lateral to the FN
- Confluent shape (24 of 39, 61%): an absent, an incomplete or bridge-shaped chordiculus is present, and the FS is confluent to the LTS

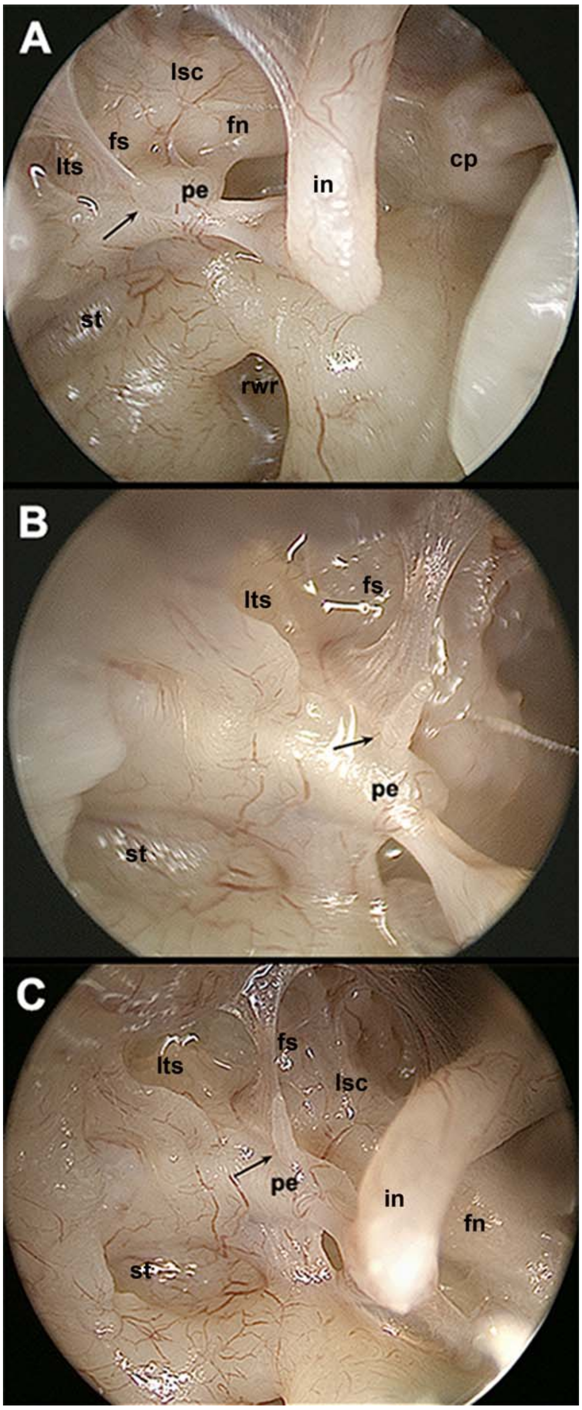

Fig. 4. Endoscopic assessment of the fs with different angled endoscopes. (A) 0° endoscope. (B) 45° endoscope. (C) 70° endoscope (fundus of the fs can be entirely visualized). Black arrow indicates an incomplete *chordiculus*. cp = choclealiform process; fn = facial nerve; fs = facial sinus; in = incus; lsc = lateral semicircular canal; lts = lateral tympanic sinus; pe = pyramidal eminence; rwr = round window region; st = sinus tympani. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Radiologic–Endoscopic Correlation

The endoscopic assessment of all the temporal bones was matched with the radiomorphologic classification.

Of the 18 type A facial sinuses, 11 of 18 (61%) could be totally explored by means of a 45° endoscope and 17 of 18 (94%) by means of a 70° endoscope; however, none could be assessed by a 0° endoscope.

Of the nine type B facial sinuses, six of nine (67%) could be totally explored by means of a 70° endoscope, whereas only one of nine (11%) by a 45° endoscope and none by 0° endoscope.

Of the four type C facial sinuses, one of four (25%) could be evaluated by means of a 70° endoscope and a 45° endoscope, whereas none were entirely visualized with the 0° endoscope.

DISCUSSION

The retrotympanum is one of the most variable areas of the middle ear cleft. In literature, several authors have already studied the anatomy of this region. In particular, present authors have already described from an endoscopic perspective the ST,[2,3] the pyramidal eminence with the subpyramidal space,[4] the sinus subtimpanicus, and the round window niche[9] with the subcochlear canaliculus.[5] In 1969, Proctor had already described the microscopic surgical anatomy of the posterior tympanic wall and defined a system of sinuses around several permanent projections of the styloid complex, such as the pyramidal eminence, the styloid eminence, and the chordal eminence.[10] The sinuses of the retrotympanum were the ST and PTS (positioned medial to the facial nerve), and the LTS and FS (positioned lateral to the facial nerve).

In 1888, Sappey was probably one of the first to describe FS. Sappey named this the *suprapyramidal fossa* due to its position in relation to the pyramidal emincence.[6] Nowadays, some authors still acknowledge Sappey by referring to the biggest cell of the pneumatization of the FS as *suprapyramidal fossula of Sappey.*[11]

Previous authors[6,7] described an inconstant bony ridge inferiorly to the FS, running from the roof of the pyramidal eminence toward the chordal eminence, where the chorda tympani enters the tympanic cavity. This structure was originally called the *chordal ridge*. Based on the results of our study, a bridge-shaped morphology was identified in seven of 39 (18%) specimens. Indeed, to the best of present authors' knowledge, this is the first time that such anatomic variation is described. Thus, the term *chordal ridge* would be inappropriate in a relevant percentage of cases. For this reason, the term *chordiculus* is herein introduced, also according to universally accepted nomenclature used to describe other retrotympanic structures.

As mentioned above, several authors described this area from a microscopic point of view because it represents access to the middle ear cavity through the posterior tympanotomy in transmastoid route. Parlier-Cuau et al. conducted a radiologic study based on CT scans of 66 disease-free temporal bones, studying several retrotympanic structures, among which there were also the LTS, FS, and ST. Radiologic detection of all these landmarks was variable. The *chordiculus* was detected in 52% of the cases, the ST in 95%, and the FS in 80%.

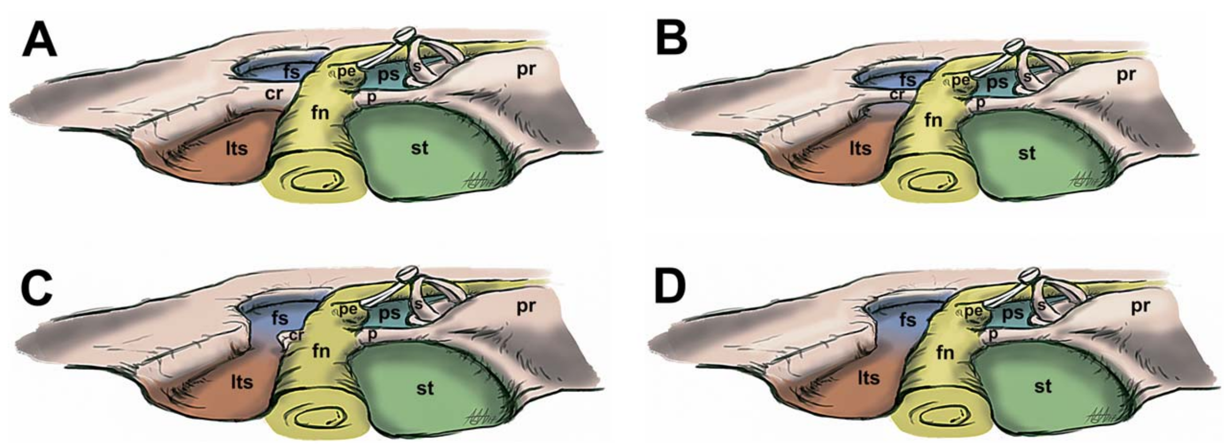

Fig. 5. Sample drawing showing the morphological variations of the *chordiculus*. The presence and the type of the *chordiculus* influences the shape of the fs (classic vs. confluent). (A) Ridge *chordiculus* and classic shape fs. (B) Bridge *chordiculus* and confluent shape of fs. (C) Incomplete *chordiculus* and confluent shape of fs. (D) Absent *chordiculus* and confluent shape of fs. cr = *chordiculus*; fn = facial nerve; fs = facial sinus; lts = lateral tympanic sinus; p = ponticulus; pe = pyramidal eminence; pr = promontory; ps = posterior sinus; s = stapes; st = sinus tympani. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

When visible in axial sections, the FS appeared pneumatized in 41% of the specimens, and it was reported that its average depth was 2.2 mm.[12]

Cheiţă et al., in a study based on anterior dissections of 37 temporal bones, demonstrated the variability of the anatomy of the retrotympanum, underlining that the presence of all four recesses is not a rule and that variability in size, shape, and internal configuration is very common. They found that the depth of the FS ranged from 1.45 to 3.11 mm (with an average depth of 2.28 mm) and also proposed a classification of the FS based on its internal configuration of pneumatized cells.[11] Because the classification system proposed by Cheiţă et al. is based on the presence and shape of air cells inside the FS, this kind of description, in the present authors' opinion, has little impact on surgical attitude. For that reason, we decided to classify FS in a way that could have direct consequences on surgery because the depth of FS could influence its endoscopic visualization, in particular with angled optics.

Williamson et al. assessed the width of the facial recess during cochlear implant approaches and reviewed the data in the literature (97 cases), demonstrating that a diameter of 2.54 ± 0.5 mm can be accepted as representative.[13]

Since the introduction of the endoscope in the otologic field, middle ear anatomy has been revisited. In fact, some of the anatomical structures that were neglected simply because they were barely visualized by microscopic approach have been carefully explored and described. In particular, the retrotympanum has been widely studied and described in several published papers. Such an interest probably is focused on this area of the middle ear because microscope-based exploration is tricky, which is why it has always been considered a blind spot for microscopic otosurgical approaches. Nevertheless, many efforts have been made to find a way to improve surgical exposure of this region.[14–17] Moreover, several authors have already shown how common is the residual cholesteatoma in this area and its subsites,[18,19] which is probably due to poor visualization of traditional approaches that cannot permit complete removal of cholesteatoma matrix. Thomassin et al. found that the completeness of disease eradication had significantly improved by the endoscope.[20] Subsequently, several other authors confirmed that TEES offered suitable access to various middle ear lesions, determining a significant reduction in the frequency of open tympanoplasties and recourse to posterior tympanotomy.[18,19,21,22]

The present study shows that endoscopic exploration of the lateral recesses of the retrotympanum is feasible and allows thorough assessment of all the subsites and relationships with adjacent structures (e.g., mastoid portion of FN, lateral semicircular canal, chorda tympani) by means of angled scopes. In fact, in only two of 39 (5%), the FS could be entirely explored with a 0° scope, whereas the percentage roses up to 51% with the 45° scope and up to 81% with the 70° scope.

Moreover, high-resolution 1-mm slice CT scan can predict which scope could better fit to entirely assess the depth of the FS. More than the half of the type A FS could be assessed by a 45° scope, even if 94% type A and 67% type B FS were perfectly explored with a 70° scope. Given the rarity of the FS type C (2 of 31) and the small group of specimens studied, further studies should be made to confirm our results.

In the author's opinion, knowledge of the FS can be important for otosurgeons, especially during surgery for cholesteatoma. In fact, the FS could potentially harbor residual cholesteatoma matrix, especially if the space is very deep and its exposure is not easy. For this reason, the present authors would recommend endoscopic exploration of this region in case of suspected involvement. Moreover, an adequate and detailed knowledge of the retrotympanic spaces could help in reducing iatrogenic damages to the facial nerve.

CONCLUSION

FS can be explored by endoscopic approaches to the middle ear. Angled optics (45° and 70°) may be necessary to completely visualize this space, particularly for deeper sinuses, and should be used systematically. FS can be radiologically classified in type A, B, and C, based on its relationship to the mastoid tract of FN, in the same way previously described for ST. *Chordiculus* can have different shapes (ridge, bridge) and can be incomplete or absent. The shape of *chordiculus* can influence the different conformations that the FS can have (e.g., normal, confluent). In the author's opinion, anatomic knowledge and correct interpretation of the radiologic aspect of FS may have clinical consequence in reducing residual cholesteatoma and could potentially reduce the risk of damages to the facial nerve.

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