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Original Article

Endoscopic Findings on Facial Nerve Anatomy During Exclusive Endoscopic Stapedotomy: Clinical Considerations and Impact on Surgical Results

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BACKGROUND: Variations along the facial nerve (FN) course present considerable challenges in the surgical treatment of otosclerosis, often complicating the procedure. Existing knowledge of its tympanic tract and its implications primarily comes from microscopical procedures. This study aims to assess endoscopic findings of FN anatomy in a healthy tympanic cavity and its impact on the stapedotomy procedure, focusing on the risk of complications and functional hearing outcomes.

METHODS: A retrospective study on exclusive endoscopic stapedotoplasties between October 2014 and October 2021 at our Otorhinolaryngology University Department was carried out. An evaluation of intraoperative endoscopic findings reviewed in surgical descriptive and/or video records was conducted to assess their potential negative impact on the surgery. Demographic data, preoperative and postoperative hearing thresholds, as well as intraoperative and postoperative complications were analyzed.

RESULTS: One hundred fifty-seven subjects were included. A FN partially overhanging the oval window was observed in 7.3% (n = 12): 10 prolapsing with bony canal dehiscence and 2 without any detected dehiscence. Each procedure was successfully completed without any issues related to the anomalous anatomy, and in no case, switching to the microscope for the handling of the prosthesis near the dehiscent nerve was required. No facial paralysis occurred, with an early- or long-term postoperative House–Brackman grade of 1 (n = 157, 100%). Only 3/157 patients (1.9%) showed a sensorineural threshold reduction of ≥20 dB HL, but a significant air–bone gap improvement was observed (mean closure of 18.36 dB HL, $P < .0001$).

CONCLUSION: The endoscope promotes a concrete description of tympanic FN anatomy, and endoscopic stapes surgery appears to be a safe and viable option when dehiscent or prolapsed FNs reduce the footplate's exposure.

KEYWORDS: Anatomy, endoscopy, facial nerve, otosclerosis, stapes surgery

INTRODUCTION

Anatomical variations along the facial nerve (FN) course may be of significant concern in the surgical treatment of otosclerosis, and they eventually affect the success of the procedure. In both microscopic and endoscopic stapes surgery, the relevant and hindering role is played by the second portion of the FN, which may be dehiscent, overhanging, or both.[1] Facial canal dehiscence is the most common variation, which is of even more relevance if a prolapse coexists as it may reduce access to the footplate and increase surgical stress due to a higher risk of FN injury.

The gold standard of stapes surgery has traditionally been a microscopic transcanal approach. Despite that, in recent years, there has been an increasing trend in the use of the endoscope for several otologic pathologies, including otosclerosis. In this scenario, the endoscopic ability to look "behind the corner" unravels its full potential, particularly in demanding settings such as revision cases or in front of an aberrant FN course.[2] When physical and audiological examinations strongly suggest otosclerosis and the pathology is bilateral, preoperative radiological assessment before stapes surgery is not routinely mandatory. Additionally, no specific criteria

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have been established to evaluate technical intraoperative difficulties. Nevertheless, computed tomography (CT) is mandatory when clinical suspicion occurs or in the pediatric population, in order to rule out other potential etiologies, such as ossicular chain fixation or anomalies as well as third-window syndromes. Moreover, it appears to be helpful in evaluating the fallopian canal, as specific scans may lead to modifications of the strategy with regard to the approach and surgical technique used.[3]

Facial nerve findings during stapedoplasties available in the literature mostly derive from microscopic procedures. Given the raising use of the endoscope for stapes surgery, the aim of the present study is to evaluate the endoscopic prevalence of FN variations in a healthy tympanic cavity and their surgical influence, focusing on how these variations could affect the procedure in terms of risk of complications and functional hearing outcomes.

MATERIAL AND METHODS

This is a retrospective study on patients with otosclerosis who underwent exclusive endoscopic stapedotoplasties between October 2014 and October 2021 at the Otorhinolaryngology Department of Verona University Hospital. The study's inclusion criteria encompassed patients who underwent either first-time or revision endoscopic stapedotomies as well as those who initially underwent stapedotomies but had an intraoperative conversion to stapedectomy. When the procedure was performed bilaterally, both ears were taken into account. In addition to otosclerosis, the study also included cases with the diagnosis of stapes malformation. The enrolled population consisted of patients aged 6 years or older, as we usually do not perform stapes surgery on younger children.

On the other hand, exclusion criteria consisted of patients who did not meet the age requirements, individuals with a history of chronic otitis or prior ear surgeries other than stapedoplasties, and all microscopic stapedoplasties.

In cases of bilateral conductive hearing loss highly suspected for otosclerosis, no radiological assessment was conducted. However, for all pediatric patients and those with unilateral conductive hearing loss, temporal bone CT scans were recommended.

To evaluate FN findings and their impact on surgical maneuvers, a meticulous review of intraoperative records was conducted in order to detect any FN abnormalities. Dehiscence is defined as a bony defect of the Fallopian canal with partially or entirely uncovered FN, while prolapse refers to a nerve inferiorly and anteriorly displaced to cover the oval window. Moreover, our evaluation encompassed multiple aspects, including the grade of exposure of stapes and oval window area in relation to FN anatomy, the necessity of bone removal from the scutum to improve exposure along with various techniques, instances where surgery had to be halted or shifted to a microscopic approach due to FN anatomical variations, and hearing outcomes, particularly in cases with abnormal FN courses. Data concerning intraoperative and postoperative complications were collected.

MAIN POINTS

- Difficult oval window exposure due to overhanging facial nerve.
- Surgical impact of facial nerve anatomy in stapes surgery.
- Role of the endoscope.

The House–Brackman scale was used to classify preoperative and postoperative nerve function, as it guarantees a clinically reliable and repeatable measure of the 5 main branches.[4]

Preoperative and postoperative pure tone audiograms were lastly carried out for all patients. According to the American Academy of Audiological Guidelines,[5] the bone-conduction (BC) and air-conduction (AC) thresholds were calculated as the average for 0.5, 1, 2, and 3 kHz. The air–bone gap (ABG) was reported as the difference between the pure-tone average (PTA) for AC and pure-tone average for BC at the aforementioned frequencies. Additionally, in order to define the safety of endoscopic stapedotomies in difficult conditions, sensorineural hearing loss was defined as a reduction equal to or greater than 20 dB on pure-tone average bone conduction (PTA-BC).

All of the procedures involving human participants were in accordance with the ethical standards of the institutional research committee of Verona University (Comitato Etico per la Sperimentazione Clinica delle Province di Verona e Rovigo 265/31) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent following a detailed explanation of the procedures was obtained directly from patients or from the parents/guardian of the child in the case of children under the age of 18.

Surgical Procedure

The procedures were performed under general anesthesia by a single experienced surgeon (D.M.) with rigid 3 mm endoscopes of both 0° and 45°. Intraoperative facial nerve monitoring (NIM) was used in all the cases. After infiltration of the posterior external auditory canal, an incision from the 5 to the 12 o'clock position was made to harvest a tympanomeatal flap, preserving its malleolar attachment. In most cases, part of the scutum was removed with a bone curette or piezoelectrically (Mectron Piezosurgery®, Medical Technology, Italy). Exploration of the middle ear allowed careful evaluation of the fallopian canal's bony status and of the tympanic FN, which runs closely to the oval window and footplate. Once the audiological diagnosis of otosclerosis has been intraoperatively confirmed by testing stapes fixation and ruling out other differential diagnoses by assessing ossicular chain mobility with an otologic hook, stapedotomy is performed via a traditional approach. A calibrated platinotomy using a 0.6-mm-diameter diamond microdrill (Skeeter®, Otologic Drill System, Medtronic, Ireland) was performed. A piston-type titanium prosthesis of 0.6 × 4 or 6 mm (K-Piston stapes prosthesis, Kurz, Germany) was placed between the oval window and the incus, and its hook was then closed to the long process. Lastly, round window movement was checked by gently pushing on the malleus, and the tympanomeatal flap was relocated into its original position.

Statistical Analysis

Statistical tests were carried out using R, version 3.6.3 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria). Continuous data were expressed as mean ± SD or percentage. To evaluate hearing outcomes and safety in terms of bone conduction preservation, preoperative and postoperative audiological data were compared

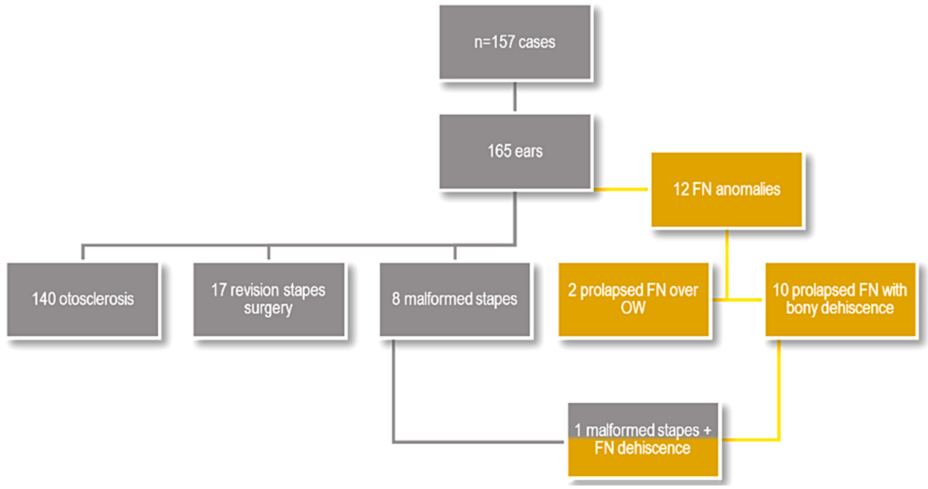

Figure 1. Population of study flowchart with surgical indications and facial nerve findings.

using a paired Student's *t*-test. *P*-values < .05 were considered statistically significant.

RESULTS

One hundred fifty-seven patients underwent exclusive endoscopic stapedoplasties (Figure 1). Considering 8/157 patients (5.1%) had bilateral procedures, the total amount of treated ears was 165. Among these, 67/157 (42.7%) were males, while 90/157 (57.3%) were females, with a mean age of 48.28 ± 12.02 years. Five patients (3.2%) represented a pediatric subgroup being 17 or less years old. For what concerns side, 99/165 (60.0%) were right ears, while 66/165 (40.0%) were left.

Otosclerosis represented the major intraoperative finding (n = 140), while among others, 17/165 (10.3%) were revision surgeries and 8/165 (4.9%) had conductive hearing loss due to various stapes malformations. Within the latter, 3 were hypoplasic stapes, 3 had suprastructure malformations, and 2 were monopodalic (single crura).

From surgical data, in 52/165 ears (31.5%), the stapes region was adequately exposed after tympano-meatal flap elevation, and no external auditory canal drilling was required. Conversely, posterior auditory canal drilling was necessary to display the oval window niche in 113/165 (68.5%) cases, of which 112 by using a bone curette and 1 with the aim of piezosurgery. A 0.6-mm-piston was used in all patients. Mostly no sealing was placed on the oval window surrounding the piston, except when platinectomies were performed instead of stapedotomy, with heterologous materials being the first choice (Lyoplant, n = 7), followed by temporal muscle fascia (n = 2). In such cases, a stapedectomy was performed as a result of an accidental footplate fracture rather than a difficult oval window exposure caused by an abnormal FN.

Focusing on intraoperative endoscopic findings, an anomalous course of the FN was detected in 12 out of 157 patients (7.64%). Out of 157 patients, 10 (6.37%) showed dehiscence of the FN along its tympanic tract (Figure 2), and 2 (1.27%) had prolapsed FNs without reported dehiscence. In all cases (n = 12), the oval window was only partially visible; however, in no case was it found to be completely concealed. One patient (1/12, 8.33%) presented an association between facial canal dehiscence with FN prolapse and suprastructure malformation. No bilaterality appeared, considering endoscopic FN findings in those patients who underwent bilateral stapedotomy. The stapedotomy procedure was successfully completed in all cases

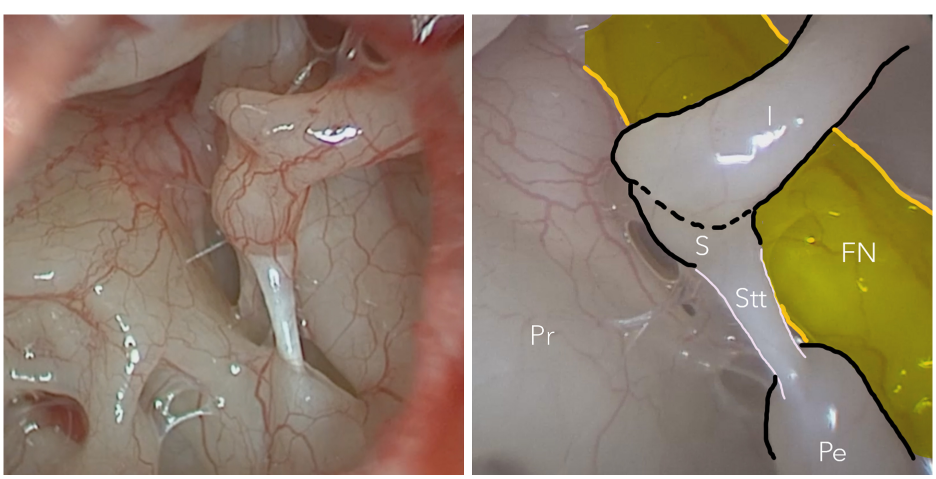

Figure 2. Endoscopic findings of facial nerve prolapse and dehiscence partially overhanging the oval window in 2 different stapes surgeries. Pr: promontorium; I: incus; S: stapes; Stt: stapedial tendon; Pe: pyramidal eminence; FN: facial nerve.

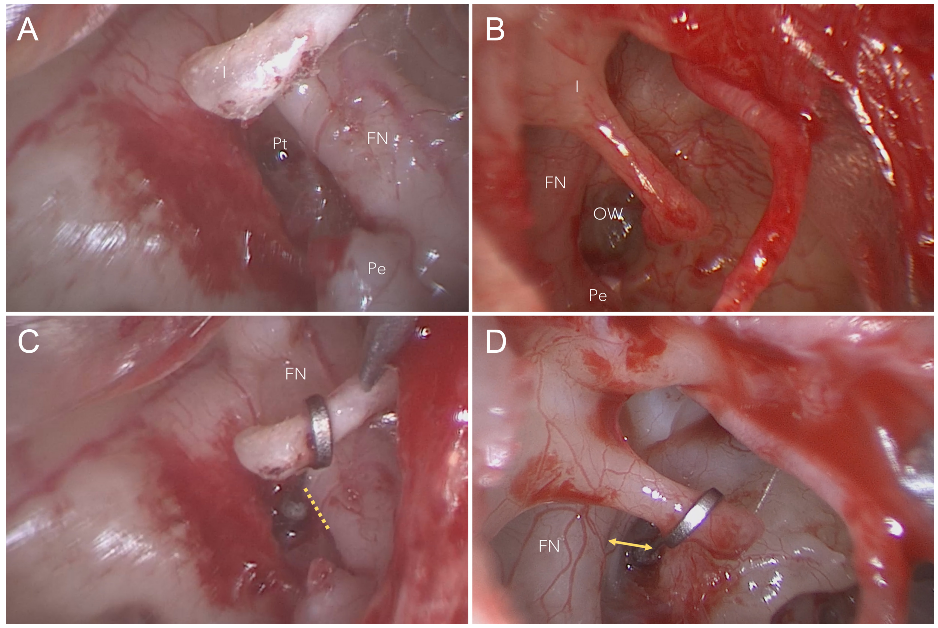

Figure 3. Relationship between facial nerve and oval window niche (A,B) and stapes prothesis (C,D). I: incus; FN: facial nerve; Pe: pyramidal eminence; Pt: platinotomy; OW: oval window. The yellow dotted line and the yellow arrow show different distances between the dehiscent (C) or regular (D) facial nerve and the prothesis just placed.

without any need for intraoperative surgical strategy changes or shifting to the microscope for a 2-handed procedure, aside from 1 out of 157 patients (Figure 3). Furthermore, in all individuals with FN abnormalities (12/12, 100.00%), a platinotomy was performed as planned, and in none of them (0/12, 0.00%), the prosthesis has been anomalously placed due to unfavorable anatomy.

All patients clinically presented with a preoperative House–Brackman grade of 1. Facial paralysis was not observed in any cases in the early or long-term postoperative period, with a postoperative House–Brackman grade of 1 (n = 157, 100%).

No major complications such as dead ear or permanent facial palsy have been encountered, while a few minor complications occurred, such as temporary vertigo with spontaneous (n = 7, 4.5%) or without-spontaneous nystagmus (n = 4, 2.6%), tinnitus (n = 3, 1.9%), and dysgeusia (n = 3, 1.9%).

Among intraoperative complications other than FNs, accidental platinectomy was the most commonly reported and occurred in 9 cases (5.5%). Others encountered were 5 small tympanic membrane perforations (3.0%), 2 chorda tympani sections (1.2%), and 2 gushers (1.2%), one of which required a revision surgery a few days later with an Eustachian tube and tympanic cavity obliteration. Lastly, even in the case of dehiscence, no endoscope-related thermal injury was reported, as no short-term FN dysfunction appeared.

Table 1. Preoperative and Postoperative Hearing Results

	Preoperative (dB HL)	Postoperative (dB HL)
Pure-tone average air conduction	54.67 ± 15.72	33.42 ± 17.42
Pure-tone average bone conduction	26.29 ± 11.21	23.40 ± 14.57
Mean air–bone gap	28.37 ± 9.80	10.01 ± 8.42

Audiological hearing data were completely available for 161 ears (97.6%) (Table 1). Within the preoperative hearing assessment, a BC of 26.29 ± 11.21 dB HL was found (6.25-65), while the AC was 54.67 ± 15.72 dB HL (16.25-107.5). The corresponding ABG was 28.37 ± 9.80. Postoperative thresholds showed a BC of 23.40 ± 14.57 dB HL and an AC of 33.42 ± 17.42 dB HL, with an ABG of 10.01 ± 8.42. In terms of sensorineural preservation, a reduction equal to or greater than 20 dB HL was observed in 3 patients (1.9%), with a mean loss of 38.5 ± 7.60. A significant improvement between preoperative and postoperative ABG was observed ($P < .0001$), with a mean closure of 18.36 dB HL, as minimum a worsening of 21.25 dB HL and as maximum an improvement of 48.75 dB HL.

DISCUSSION

Iatrogenic facial palsy is one of the most fearsome otosurgical complications. A key role is played by in-depth knowledge of the anatomical features of the FN and its middle ear course. A dehiscence is a bony defect of the Fallopian canal with an exposure of epineural tissue, while FN prolapse refers to a nerve overhanging the stapes footplate. Among FN abnormalities, canal dehiscence is the most common variation, with overall findings ranging between 5.3% intraoperatively and 29.6% from autoptic specimens.[6,7] One of the largest series in the literature comprises 144 various otologic procedures, in which 11% of the population presented FN dehiscence. More in detail, Yetiser microscopically classified the facial canal into 5 groups according to the site of dehiscence (i.e., geniculate ganglion, horizontal segment, at the second genu, only over the oval window niche, and vertical segment) and found that the tympanic segment, including the second genu and the oval window region, was the most commonly involved.[8]

Regarding patients suffering from otosclerosis, in whom the tympanic cavity is regular apart from an otospongiotic process, a retrospective analysis of 147 stapedotomies showed an abnormal FN in 28.57% of ears, with prolapsed being the most frequent (18.37%).

Nevertheless, no prognostic factors were found, and these prolapses did not statistically influence audiological outcomes. However, this rate seems to be overestimated by an inadequate or simply difficult oval window exposure as well as incorrect microscope positioning, a concrete scenario in microscopical procedures.[9] The absence of influence on surgical outcome is also reported by Neff et al in a chart review of 1497 primary stapedotomies, where FN prolapse to any degree was encountered in 40 cases (2.6%) and a prolapsed FN covering 50% or more of the oval window in 28 (1.9%). The authors observed no statistical difference in postoperative ABG closure, albeit a discrepancy up to 10 dB appeared.[10] Moreover, even if no short- or long-term facial complications occurred, a risky maneuver of FN retraction was described when the first attempt to get control of the visible portion of the footplate was not feasible.[10,11] In comparison, we performed no manipulation of FN to gain access to the proper footplate site of drilling, as the endoscope itself guarantees adequate exposure to the area.[12] Furthermore, in accordance to the above-cited studies, an overall significant improvement between preoperative and postoperative ABG was observed in our cohort too ($P < .0001$, mean closure of 18.36 dB HL), though we did not perform any statistical comparison due to the groups' heterogeneity.

A literature review of FN findings, all derived from microscopic experiences, is summarized in Table 2 (Table 2), showing a wide range of prevalence. In this context, our results concerning endoscopic FN findings appear to be comparable to the microscopical ones in the literature, with the present value of 7.3% strengthening other available results due to a better view on tympanic structures. Li and Cao in a reported frequency of epineurium's exposure of 11.4% and of prolapsed FN of 2%-7% among 1465 stapedectomies, found bilaterality in just 12 patients.[1] This low rate of bilaterality is in accordance with our results, where no bilaterality in terms of dehiscences or prolapses were detected. Such findings could be explained by the fact that the etiology of a prolapsed or dehiscent FN is mostly idiopathic and that there is no concrete reason for a contralateral comparable finding subsists.

The prevalence of fallopian canal defects is well known to be higher in the pediatric population, as children more commonly present with incomplete ossification. This finding is even more evident when associated with malformed stapes, since FN and stapedial structure share the same embryological origin. In a cohort of 62 stapes surgeries for congenital fixation, an aberrant tympanic FN was found in 7 ears (11.2%).[13] Among the 5 pediatric patients enrolled in our study (3.2%), the youngest one was 6 years old, as we usually do not perform stapes surgery under the age of 6, consistent with the literature.[14,15] Considering this limited subgroup, 1 patient presented with a dehiscent and prolapsed nerve (1/5, 20.0%),and thus 1 out of 12 patients with overhanging FN (8.3%) belonged to the pediatric population.

It seems reasonable to state that the true prevalence may be underestimated, as small dehiscences may not be detected intraoperatively during microscopic procedures. In this scenario, the endoscope unravels even microdehiscences, as they are classically bony gaps smaller than 0.4 mm.[16] However, microdehiscences are not usually of real concern during otosurgical procedures.

The use of the endoscope in otologic procedures ensures a complete visualization of the retrotympanic surgical subareas and allows surgeons to completely visualize anatomic variations along with any pathologic tissue.[17,18] Endoscopic stapes surgery is a safe and effective procedure and adds to the traditional microscopic approach the advantage of an extremely detailed exploration of the whole tympanic cleft with a safe suprastructure's excision.[19]

In this scenario, the second portion of FN as well as the stapedial crura and oval window can be easily explored with a 0° or 45° endoscope. This is clearly advantageous when anatomic abnormalities make a normal procedure more challenging, as happens in cases of fallopian canal defects or stapes malformations.[2,11,20]

Endoscopically, a pre- and post-cochleariform FN are identified.[21,22] The former lies superiorly and anteriorly to the posterior bony limit of the cochleariform process, while the latter runs parallel posterior to the lateral semicircular canal. Within the tympanic tract, the post-cochleariform segment is the one of concern during stapes surgery.

All our ears received a piston-type titanium prosthesis measuring 0.6 mm. Performing an exclusive endoscopic procedure allowed us to avoid the need for smaller-diameter pistons, which are classically preferred in cases of unfavorable anatomic conditions such as dehiscent or overhanging FN or narrow oval window niches. Anyway, despite a suspected tendency toward better hearing outcomes with the use of larger-diameter prostheses, a systematic review evaluating the effect of piston diameter in primary stapedotomy showed no significant difference in terms of hearing performance and safety.[23]

A theoretical disadvantage of the endoscope is that it does not grant binocular 3-dimensionality and depth perception. However, just moving the endoscope within the tympanic cavity along with another tool helps to conceive a sense of spatial configuration.[24] Moreover, criticism might arise in regard to prosthesis' positioning in a 1-handed technique, which is more difficult compared to the microscopical 2-handed technique. This is actually why endoscopic stapedotomy should be the last step of an appropriate endoscopic skill training.[25] Indeed, with regard to our series, satisfactory hearing outcomes were obtained with no prothesis displacement or ossicular chain disarticulation.

As reported by Presutti et al, the endoscopic approach represents a viable and effective option, especially in the case of a predicted "difficult anatomy."[20] How such a difficult oval window exposure can be predicted still remains a question mark. Computed tomography (CT) is not mandatory in otosclerosis' preoperative assessment, though it is recommended by most otological referral centers for differential diagnosis and unilateral cases. Computed tomography scans are generally valuable for distinguishing between various conditions, such as Paget's disease, superior semicircular canal dehiscence, middle ear malformations, congenital stapes fixation, and tympanosclerosis. While we do not routinely suggest any radiological assessment in front of a bilateral conductive hearing loss highly suspected for otosclerosis, we conversely indicate temporal bone CT in all pediatric patients as well as in those with unilateral conductive hearing loss. In such cases, imaging evaluation is vital to rule out other reasons of ossicular chain fixation or anomalies

Table 2. Facial Nerve Findings: Literature Review

Authors (year)	Study	Type of Surgery	Population (Number of Ears)	Facial Nerve Findings
Moreano EH et al (1994)[36]	Histological study	Temporal bone dissection (i.e. entire course of facial nerve)	1000	Dehiscence 56.0% Microdehiscence 32.9%
Li and Cao (1996)[1]	Retrospective operative study	Microscopic stapedectomy/stapedotomy	1465	Dehiscence 11.4% Dehiscence with protrusion 6.96%
Tange and Bruijn (1997)[37]	Retrospective operative study	Microscopic stapedotomy	427	Dehiscence 3.27%
De la Cruz A. et al (1999)[15]	Retrospective operative study	Microscopic stapedectomy (children)	83 (primary) 12 (revision)	Dehiscence 16.0% Dehiscence 18.0%
Lippy WH et al (2001)[6]	Retrospective operative study	Microscopic stapedectomy	3600	Dehiscence or overhang 5.3% Dehiscence 2.8% Overhang 2.5%
Neff BA et al (2004)[10]	Retrospective operative study	Microscopic stapedectomy	1497	Prolapse 2.6% Prolapse >50% 1.9% Dehiscence 0.8%
Di Martino E et al (2005)[7]	Prospective operative study	Microscopic tympanoplasty/stapedoplasty	357	Dehiscence 6.4%
	Histological study	Temporal bone dissection (i.e. entire course of FN)	150	Dehiscence 29.4% (93% oval window region)
Vincent R et al (2006)[38]	Prospective operative study	Microscopic laser stapedotomy	3050	Dehiscence 5.7%
Gerard JM et al (2008)[9]	Retrospective operative study	Microscopic stapedotomy	147	Procident nerve 18.37% Dehiscence 2.72% Both 7.48%
An YS et al (2014)[13]	Retrospective operative study	Microscopic stapedotomy for congenital stapes fixation	62	Anomalous facial nerve 11.2%
Kozerska M et al (2016)[26]	Prospective radiological study	Micro-CT on temporal bones	36	Dehiscence 66.7%
Fernandez IJ et al (2019)[20]	Retrospective operative study	Endoscopic stapedotomy	205	Dehiscence covering oval window 0.9%
Senturk E et al (2020)[11]	Prospective operative study	Microscopic stapedectomy	28	Dehiscence or prolapse 39.3%
Tang R et al (2023)[27]	Retrospective operative and radiological study	Microscopic mastoidectomy/tympanoplas ty/stapedoplasty	40	Dehiscence 72.5%

(such as cochlear incomplete partitions) as well as third-window syndromes. A more detailed radiological evaluation concerning FN was proposed in a study from Tankere et al, looking at both the width and depth of the oval window niche and at the facial-promontory angle. A comparison between these values and those found intraoperatively confirmed their role in predicting FN overhanging, the narrowness of the oval window niche, and surgical difficulty.[3] Within the context of FN abnormalities, the ability of imaging techniques to characterize the facial canal's microstructure is limited. Application of computed micro-tomography (micro-CT) with a resolution of 18 µm was suggested in describing fallopian canal defects in terms of size, shape, and location, with a partial lack of the osseous wall within the tympanic segment observed in 66.7% of subjects (n = 36 temporal bones).[26] Recently, Wang et al, with the aim of ultra-high-resolution CT (U-HRCT), classified the imaging appearance of the lateral and inferior walls of the tympanic facial canal into 4 types, from no evident to continuous bone covering, and proposed a novel dehiscence's scoring method as the sum of lateral and inferior scores.[27] Similarly, Zhang et al demonstrated how U-HRCT images could reveal a downward protrusion of the tympanic segment of FN and measured some quantitative indices from simple radiological landmarks that might predict an overhanging FN; among these, the distance between FN and both anterior and posterior stapes crura significantly appeared as 2 independent predictors.[28] To date, a considerable issue of such promising radiological assessments is that they are mostly still experimental and not daily available for clinical practice. Multi-slice spiral computed tomography (MSCT) is conversely widely applied. Kang et al demonstrated its widespread application by establishing the clinical significance of coronal MSCT multi-planar reconstruction in detecting a downward and inward shift of the tympanic segment of the FN covering the oval window in patients with simple middle ear malformations.[29] In terms of surgical complications, the finding that no FN injury occurred is consistent with what is reported in the literature, with an overall postoperative FN weakness of 0.8%.[30] Among other adverse events encountered in our series, 2 gushers out of 165 patients (1.2%) have been the ones of most concern. One preoperative and both postoperative radiological evaluations did not detect any cochlear anomalies or cochlear aqueduct enlargement, which would have been suggestive of potential intraoperative leakage.[31] Although no pathognomonic signs have been identified yet, a slight enlargement of the ipsilateral internal auditory canal fundus was observed in the imaging review of the most critical patient, which could be retrospectively linked.[32] Treatment for the patients varied: one patient's mild perilymphatic leak was managed by covering the oval window, while in the other, switching to the microscope was necessary to handle the gusher and fill the tympanic cavity with temporalis muscle.[33]

Lastly, one aspect endoscopic surgeons should take care of especially in front of a dehiscence is the possible thermal damage derived from closeness to a light source. The tip of an endoscope with different light sources set both at maximum and medium intensity might reach a temperature up to more than 40°C.[34] To reduce any sort of heat damage, the authors suggest the use of submaximal light intensity, frequent aspiration or intermittent irrigation, and repositioning of the endoscope allowing tissue cooling. In our series, we have never encountered thermal damage thanks to these precautions, even when working in close proximity to the dehiscent nerve. Even if the exact heat tolerance of the FN is not established, a study conducted with ultrasonic irradiation of the labyrinth for Ménière's disease suggested that it can tolerate a temperature of up to 46°C.[35]

The limitations of the present study were a retrospective analysis, the lack of a microscopic control group, and a relatively small sample in size, especially in regard to the FN variants, which did not enable us to perform a statistical comparison between normal vs. abnormal FN. However, our aim was to evaluate the endoscopic FN findings in a non-inflamed middle ear and to compare them with the microscopic epidemiological data reported in the literature.

This is one of the first studies evaluating FN findings in stapes surgeries from an exclusive endoscopic point of view. Based on our experience, endoscopic stapes surgery provides a more detailed epidemiological and anatomical description of FN abnormalities. The closer view strengthens the data on FN prolapse and dehiscence available in the literature, while an adequate exposure of the oval window eliminates the supposed prolapsed FN seen in microscopic procedures and reveals small bony dehiscences that may remain undetected with a microscope. Furthermore, when dealing with cases of difficult footplate exposure due to an anomalous FN course, the endoscope offers better guidance for surgical maneuvers, ensuring a more gentle approach to the FN during prosthesis positioning.

Ethics Committee Approval: This study was approved by the Ethics Committee of Verona and Rovigo University (Approval No: 265/31)

Informed Consent: Written informed consent for publication of the clinical details and clinical images was obtained from the patients and guardians who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – D.S., G.R.; Design – G.R., L.S.; Supervision – D.S., D.M.; Materials – L.S., D.M.; Data Collection and/or Processing – G.R.; Analysis and/or Interpretation – D.S., L.S., D.M.; Literature Search – G.R., L.S.; Writing – G.R.; Critical Review – D.S., D.M.

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