Minimal Invasive Lateral Endoscopic Multiport Approach to the Infratemporal Fossa: A Cadaveric Study

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Conflict of Interest

The authors declare no conflict of interest.

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Abbreviations

- Infratemporal fossa (ITF)
- Internal maxillary artery (IMA)
- Maxillary nerve (V2)
- Mandibular nerve (V3)

Abstract

Objective: Expanded endoscopic endonasal approaches to the infratemporal fossa (ITF) are increasingly performed due to the improved visualization and the less morbidity in comparison to the classic open approaches. However, only a few studies in the literature investigated the lateral endoscopic access to the ITF. The purpose of our study is to examine the ITF with the minimal invasive endoscopically assisted Gillies approach with the trial of its expansion through a double port technique.

Materials and Methods: The ITF was examined in 10 sides of five cadaver heads using a lateral endoscopic assisted approach. Moreover, a double portal technique was developed to allow bimanual dissection. Specific long angled skull base instruments were used for the dissection under stereotactic guidance.

Results: The endoscopic assisted Gillies approach permitted a minimally invasive access to the complete anteroposterior extension of the ITF with sufficient mobility of the surgical instruments. A new anatomical classification for the ITF from a lateral endoscopic perspective was introduced. The addition of the second port gave the opportunity for bimanual dissection.

Conclusions: This cadaveric study shows the feasibility of an endoscopically assisted lateral approach to the ITF. Furthermore, the addition of a posterior port expands the approach through increasing the working area and enable a bimanual dissection technique. Either performed alone or in combination with an anterior endoscopic

transnasal approach, the hereby proposed technique can offer a minimally invasive access to the ITF. The development of specifically designed instruments would further improve the impact and ease of this promising approach.

Key words: Infratemporal fossa; anatomy; minimal-invasive surgery; anterolateral skull base surgery; endoscopy

Introduction

The infratemporal fossa (ITF) is an anatomically complex and surgically difficult to approach territory in the anterolateral skull base. The ITF is situated underneath the floor of the middle cranial fossa, behind the maxilla and in front of the mastoid and tympanic portions of the temporal bone. It is bordered medially by the lateral pterygoid plate, the pharynx and tensor veli palatini muscle and laterally by the deep surface of temporalis muscle and mandibular ramus.

Due to recent advancements in optical technology, the endoscopic and endoscopic assisted-surgeries allow a minimal-invasive surgical access to skull base lesions. Expanded endoscopic endonasal approaches to the ITF have been described by several authors[1-7]. These approaches are defined as a lateral expansion of the endoscopic endonasal transpterygoid approach[8]. However, these endonasal approaches have drawbacks and limitations, especially regarding the surgical exposure of the targeted area. The pterygoid process and attached masticator muscles restrict the view to the posteromedial ITF. Hence, for exposure of the foramen ovale and related structures, the lateral pterygoid plate must be drilled with resection of lateral pterygoid muscle[1-3,6,9-14], which may lead to postoperative trismus[6,9-11]. Another possible sequela is ipsilateral palatal anesthesia as a result of injury to palatine nerves[6, 9-11,15]. For the ease of instrumentation of the far lateral ITF, it is necessary to choose an endoscopic approach with extended lateral exposure such as anteriorly extended medial maxillectomy, endoscopic assisted Denker approach, trans-septal approach or endoscopic assisted sublabial anterior maxillotomy[5,16-19]. These former approaches have also the possibility of post-operative complications as lacrimal dysfunction[20], anterior septal perforation[17], alar collapse[18] and neurological issues[21].

For this reason, in cases of isolated ITF lesions or in pathologies extending posteromedially and/or laterally, it may be useful to approach the pathology from a lateral corridor. Therefore, the development and description of minimally invasive lateral approaches have been previously performed. Hartnick et al[22,23] were the first to report a lateral minimal invasive endoscopically assisted access to the ITF named the "endoscopically assisted Gillies approach". They addressed solely foramen ovale by subperiosteal dissection of the ITF through two incisions: one at the temporal hairline and one at the lateral eyebrow.

These previous studies mentioned as the main issue of this lateral approach the difficult surgical manipulation due to the lack of proper instruments to work along the cranial base curvature. Moreover, a clear outlining of the approach extension and possibilities of its expansion were not described. Also, these investigations lack the description of the endoscopic anatomy of the ITF as perceived from a lateral access. We hypothesize, that an additional posterior port to the ITF in order to introduce the endoscope to this anatomical region is beneficial for the surgical working area and so for the instrumental maneuverability. Furthermore, we aim to illustrate the endoscopic anatomy of the ITF from a lateral perspective and the area of exposure that can be reached by the approach and by its expansion through a double portal technique. We also target to describe the advantages and drawbacks of it as a solitary and as a combined approach to the ITF.

Materials and Methods

Our institutional review board granted approval to conduct the present study (KEK-BE 2016-00887). The study was conducted in accordance with the Declaration of Helsinki. To answer the study questions, we performed cadaveric dissection in silicone injected cadaver heads using a 4mm diameter, 18cm length, 45° angled rodlens endoscope connected to a light source through a fiberoptic cable and to a high definition video camera (Karl Storz GmbH, Tuttlingen, Germany). Before the dissection, a high-resolution computed tomography scan was performed for all specimens, and the images were uploaded to an image guidance system (BrainLAB AG, Munich, Germany) to be used with angled probes.

Ordinary endoscopic endonasal instruments were not suitable for manipulation around and beneath the skull base, therefore we used specific endoscopic skull base instruments (Castelnuovo set by Karl Storz GmbH, Tuttlingen, Germany). We chose mainly long angled elevators and forceps and in some areas double angled instruments. The suction irrigation sheath as well as the optical dissector with a distal spatula (Karl Storz GmbH, Tuttlingen, Germany) were very helpful tools in decreasing the need for the lens clearance.

Endoscopic dissection technique

Each head was turned to one side and a 2.5 cm long, vertical incision down to the periosteum was performed just behind the temporal hairline. Its lower limit did not exceed a horizontal line extending backward from the supraciliary arch as shown in Figure 1A. Subsequently, subperiosteal dissection of the temporal fossa was performed downwards along the slope of the greater wing of sphenoid bone to reach the infratemporal crest, the margin separating the temporal from the infratemporal fossa (Figure 2A). The periosteum was cut at the infratemporal crest to reach the attachment of the upper head of the lateral pterygoid muscle at the lower surface of the greater wing of the sphenoid bone. The former muscle had to be detached from the skull base. At this point, it is important to preserve the anterior deep temporal artery and nerve passing laterally above the lateral pterygoid muscle to supply the temporalis muscle (Figure 2B).

The exposure was started in the anterior ITF with the dissection of the internal maxillary artery (IMA) from the surrounding retromaxillary fat and following the course of the IMA until reaching its entry zone into the pterygopalatine fossa through the pterygomaxillary fissure (Figure 3A-D). The artery had several branches behind the maxilla, the constant branches were: muscular branches to lateral pterygoid, anterior deep temporal artery, infraorbital artery, and posterior superior alveolar artery. The maxillary nerve (V2) was identified superiorly with respect to the IMA. The posterior superior alveolar nerve branched from the V2 in the ITF and descended with its accompanying artery on the posterior wall of the maxilla (Figure 2C).

The lower head of the lateral pterygoid muscle was resected to expose the posterior ITF. Just behind the root of the lateral pterygoid plate, the foramen ovale with the mandibular nerve (V3) were identified (Figure 3E-F). The V3 divided just below the skull base into two trunks: an anterior smaller and posterior larger. The masseteric nerve emerged from the anterior trunk just below the V3 division and passed laterally above the lateral pterygoid muscle in front of the temporomandibular joint. Other branches observed from the anterior trunk were a branch to the lateral pterygoid muscle and buccal nerve. The latter always traveled downwards between the two heads of the lateral pterygoid muscle. The auriculotemporal nerve was the first branch arising from the posterior trunk by two roots encircling the middle meningeal artery and passing backward towards the temporomandibular joint. Further on, the posterior trunk divided into the lingual and inferior alveolar nerves which continued their course downwards.

Two branches of the maxillary artery could be distinguished in relation to V3. The first was the middle meningeal artery entering the cranium through foramen spinosum behind V3. The accessory meningeal artery was the second one and passed through the foramen ovale with V3. The tensor veli palatini muscle formed a sheath separating the posterior compartment of the ITF from the nasopharynx (Figure 4).

Approach expansion by double portal technique

A second 2 cm vertical incision was made 3 cm posterior to the first one, in line superiorly with the temporomandibular joint as shown in Figure 1B. A subperiosteal tunnel was performed directed towards the greater wing of sphenoid bone. Through this posterior portal, a narrow corridor to the infratemporal fossa was established and was used as an entry site for the endoscope.

Results

A total of ten sides (n=10) in five cadaveric heads were completely dissected following the above-mentioned directions and using the double portal technique.

Minimal invasive endoscopic double port approach

The proposed expansion of the endoscopic assisted lateral approach to the ITF was successfully performed on all sides. Through this posterior portal, a narrow corridor to the ITF was established offering only a very limited freedom of movement for surgical instruments. For this reason, the port was used to introduce the endoscope to the ITF. This allowed dissection by two surgeons, one holding the endoscope and the other performing bimanual dissection as illustrated in Figure 5. This refined technique offered important advantages during dissection of the important anatomical structures. Although not assessed in this study, the control of bleeding may be greatly improved by a bimanual technique allowing constant suctioning of blood.

Lateral endoscopic anatomical classification of the infratemporal fossa

Due to the lack of a surgical and anatomical classification of the ITF, we propose the division of the region into two compartments from a lateral endoscopic perspective. The anterior compartment is located behind the maxilla in close relation with the pterygomaxillary and the inferior orbital fissures. It contains the IMA segment after passing between the two heads of the lateral pterygoid muscle, V2 after leaving the pterygopalatine fossa through the pterygomaxillary fissure crossing the ITF on its way to the inferior orbital fissure and the retromaxillary fat in which the previous structures are embedded. On the other side, the foramen ovale is the center of the posterior compartment, containing the lateral pterygoid muscle, the proximal part of the IMA, the pterygoid venous plexus, V3 and its divisions, the lesser petrosal nerve, the otic ganglion, and the chorda tympani before joining the lingual nerve. This new classification is illustrated in Figure 6.

Surgical exposure and instrument maneuverability

The endoscopically assisted approach permitted visualization of the whole anteroposterior extent of the ITF from the posterior wall of the maxilla to the spine of the sphenoid bone. The long and angled instruments granted dissection beneath the skull base under the guidance of angled endoscopes. Frameless stereotactic guidance was found to be possible and helpful in identifying the anatomical landmarks throughout the region. The working area for the instrument maneuverability was higher in the anterior compartment of the ITF due to the presence of the slope of the greater wing of the sphenoid bone and it decreased as going posteriorly to be the least at the spine of the sphenoid bone.

The upper head of the lateral pterygoid muscle is the gate of the ITF and its removal was required for exploration of the fossa in all sides (n=10). At the same time, conserving the lower head protects the mandibular nerve and namely its posterior division. However, its resection is a requisite for complete exposure of the medial boundary of the ITF. In all circumstances, there is no need for drilling of the pterygoid plate to enhance the exposure.

Discussion

In this study, we describe a lateral endoscopic double portal approach to the ITF, allowing for its complete exploration using a bimanual surgical technique. Moreover, we describe the anatomy of the ITF from a lateral endoscopic perspective and propose a novel anatomical classification for this region. The classification may be of a great value in staging and management of ITF lesions in the future.

Traditionally, the ITF has been approached through a variety of open surgical approaches[24, 25, 26], but during the last decades with the increased application of the endoscopic surgery on different skull base regions, several expanded endoscopic endonasal approaches to the ITF have been described[1-7]. These advances were mainly intended to minimize the damage to otherwise healthy structures and therefore to improve the postoperative healing and lower the procedural morbidity. However, there are only a few reports in the literature describing the idea of a minimally invasive lateral access to the ITF[5,23], and the only clinical application reported was by Hartnick et al[22] in 2001 for diagnosis of CSF leakage through foramen ovale after subperiosteal dissection of the temporal and infratemporal fossae. Furthermore, no comprehensive description of the anatomy was provided in these studies. In contrast, we performed an anatomical examination of the whole ITF by the lateral endoscopic approach and proposed a novel anatomical classification of the region. In our opinion, the knowledge of the anatomical structures is of uppermost importance in minimally invasive surgery as the surgeon is working inside a narrow surgical field. The spatial orientation of the surgeon is the critical point to avoid injuries to anatomical structures. Moreover, the expansion of the approach through a second port in the posterior temporal area allowed us to omit the incision at the lateral eyebrow.

To benefit from the slope of the greater wing of the sphenoid bone in increasing the maneuverability of the surgical tools and to avoid the postoperative facial scaring, we found that the best site for the approach incision is in the anterior temporal region just behind the hairline. The second port is then placed 3 cm posterior to this incision, which does not have cosmetic issues. Moreover, the dual port technique as presented allowed for bimanual dissection.

The advantage of the Gillies approach over the classic anterior endoscopic approaches is the unhindered visualization of the posteromedial ITF and the ease of access and instrumentation over the lateral part of the fossa. More invasive anterior endoscopic procedures are required to reach these parts of the ITF which make approaching of this domain more complex with the possibility of postoperative complications such as trismus, palatal hypoesthesia, lacrimal dysfunction, alar collapse, septal perforation and infraorbital nerve dysfunction[6, 9-11,15,17,18,20,21].

Controversially, the endoscopically assisted Gillies approach has no control over the surrounding structures outside the ITF. Additionally, it has a gradual decrease of the maneuverability of the surgical instruments as going posteriorly from the posterior wall of the maxilla to the spine of the sphenoid bone. These considerations are summarized in Table 1.

The isolated endoscopically assisted Gillies approach can provide a fast and minimal invasive route to foramen ovale. In this case, the dissection is started subperiosteally in a downward direction from the temporal fossa and maintained in the same plane under the surface of the greater wing of sphenoid bone. Continuation in the subperiosteal plane leads to depression of the whole content of the ITF with the roofing periosteum. This procedure may be useful in case of solely targeting the foramen ovale (Figure 7).

According to Conley[27], ITF tumors are classified into 3 subsets: (A) contagious lesions, which are the most common and spread from surrounding structures to the ITF such as juvenile nasopharyngeal fibroma, inverted papilloma, meningioma, adenoid cystic carcinoma and squamous cell carcinoma, (B) primary tumors that originate from the ITF and include schwannomas, lipomas, lymphoma, adenoid cystic carcinoma and hemangiopericytoma and (C) metastatic tumors, which are rare in occurrence. We believe that the presented technique can be used as a single approach for the resection of small primary ITF tumors especially when these lesions are mainly confined to the anterior part of the fossa behind the maxilla. However, in cases of larger primary ITF tumors or contagious pathologies that spread from the nose or nasopharynx to the ITF, it can be combined with an anterior endoscopic approach even using a staged resection of the pathology.

Moreover, Eloy et al[5] showed that this access can add an endoscopic view of the posterosuperior ITF or be used as an additional corridor if combined with an anterior endoscopic approach. In our opinion, the addition of the lateral corridor may diminish the complexity and incidence of complications of the anterior endoscopic approaches through controlling some areas not easily reachable by an anterior endoscopic access. Figure 8 illustrates how the different sections of the ITF can be addressed, relative to the approach chosen in a staged surgery.

The instruments used for these dissections are originally designed for expanded endonasal endoscopic approaches. Hence, we had to reverse their capture to be able to examine the ITF from an upward position. Although these instruments were so helpful in our work, we believe developing more specifically designed instruments not only for dissection but also for coagulation will further improve the ease of the approach. In contrast to the present cadaveric study we would expect in a clinical setting a high probability of bleeding either from lateral pterygoid muscle resection, pterygoid venous plexus, the IMA itself or its branches. Clipping of the different branches would be an appropriate solution in our opinion. Moreover, the advantage of bimanual dissection through the double port technique would be certainly beneficial to the management of bleeding. In summary, the feasibility of the approach has yet to be demonstrated in a clinical setting.

Conclusion

This cadaveric study shows the feasibility of an endoscopically assisted lateral approach to the ITF. Furthermore, the addition of a posterior port expands the approach through increasing the working area and enable a bimanual dissection technique. Either performed alone or in combination with an anterior endoscopic transnasal approach, the hereby proposed technique can offer a minimally invasive access to the ITF. The development of specifically designed instruments would further improve the impact and ease of this promising approach.

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Table 1: Comparison of endoscopic transnasal approaches to the infratemporal fossa (ITF) to the endoscopically assisted lateral approach.

	Endoscopic transpterygoid approach	**Endoscopically assisted lateral approach**
Technique	Transpterygoid with resection of part of the pterygoid process *Variants:*	Subperiosteal dissection of the temporal fossa *Variants:*

	• Ipsilateral transpterygoid • Trans-septal • Anteriorly extended medial maxillectomy • Endoscopic assisted Denker approach • Endoscopic assisted sublabial anterior maxillotomy	• Mono-portal • Double-portal
Advantages	• No external skin incision • Exposure of paramedian and midline structures	• Exposure of posteromedial ITF • Easy manipulation of lateral ITF
Disadvantages	• Restricted exposure of the posteromedial ITF • Difficult manipulation of the lateral ITF *Access related complications* • Trismus • Palatal anesthesia • Lacrimal dysfunction • Septal perforation • Alar collapse • Lesion of infraorbital nerve	• External skin incision • Less specialized surgical instruments • Restricted working area for instrument maneuverability • Restricted exposure of structures outside ITF *Access related complications* • Trismus • Temporal pain with affection of the temporalis muscle
Indications	• Primary ITF lesions • Contagious lesions extending from the nose or nasopharynx to the ITF	*As single approach* • Minimal invasive access to the foramen ovale and V3 • Small primary ITF lesions *As combined approach* • Contagious lesions extending from the nose or nasopharynx to the ITF

Figure Legends

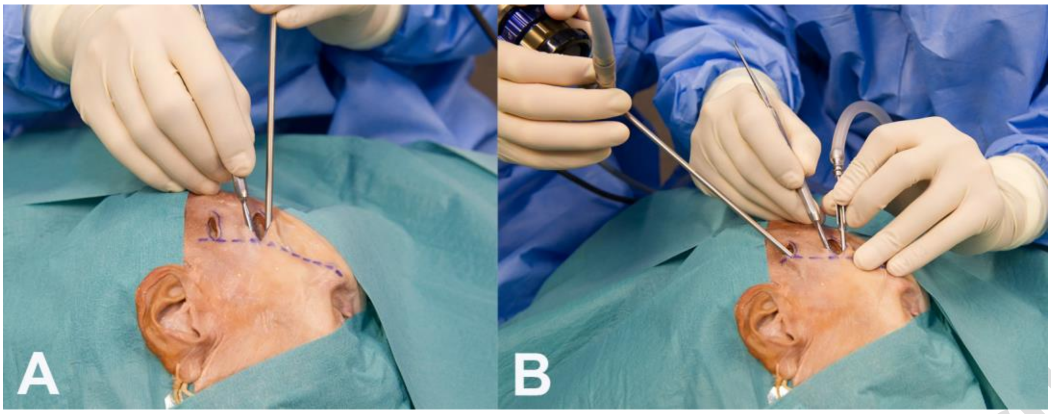

Figure 1: External incisions for the endoscopic assisted lateral approach to the infratemporal fossa (right side) with appropriate instruments inserted.

Panel A: The anterior incision (length: 2.5cm) is made just behind the temporal hairline. The dotted line indicates an imaginary line running backward from the supraciliary arch. B: The second incision for the double port variant is located 3cm posterior to the first.

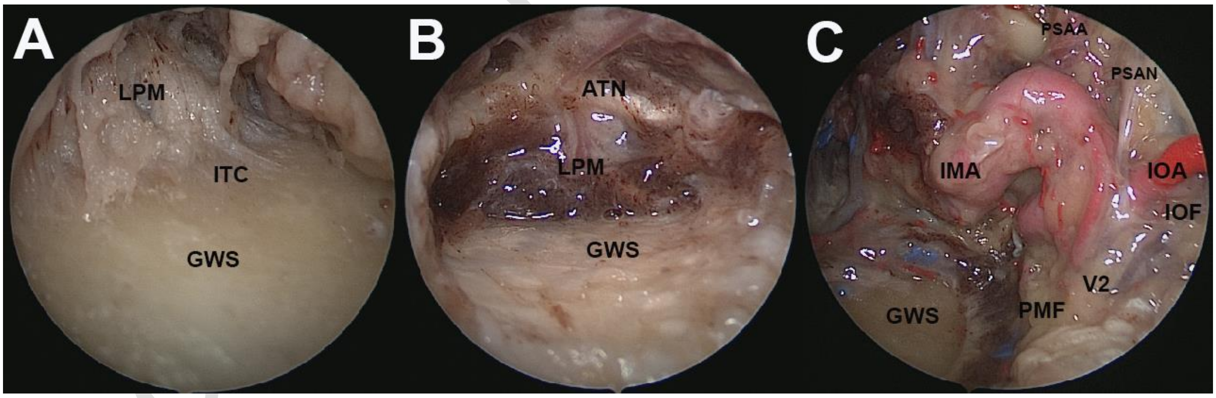

Figure 2: Endoscopic assisted lateral approach to the infratemporal fossa (ITF) (left side)

Panel A: Subperiosteal dissection of the temporal fossa; B: Detachment of the upper head of the lateral pterygoid muscle; C: Contents of the anterior ITF after removal of the retromaxillary fat.

ATN: anterior deep temporal nerve; GWS: greater wing of sphenoid bone; IMA: internal maxillary artery; IOA: infraorbital artery; IOF: infraorbital fissure; ITC: infratemporal crest; LPM: lateral pterygoid muscle; V2: maxillary nerve; PMF: pterygomaxillary fissure; PSAA: posterior superior alveolar artery; PSAN: posterior superior alveolar nerve.

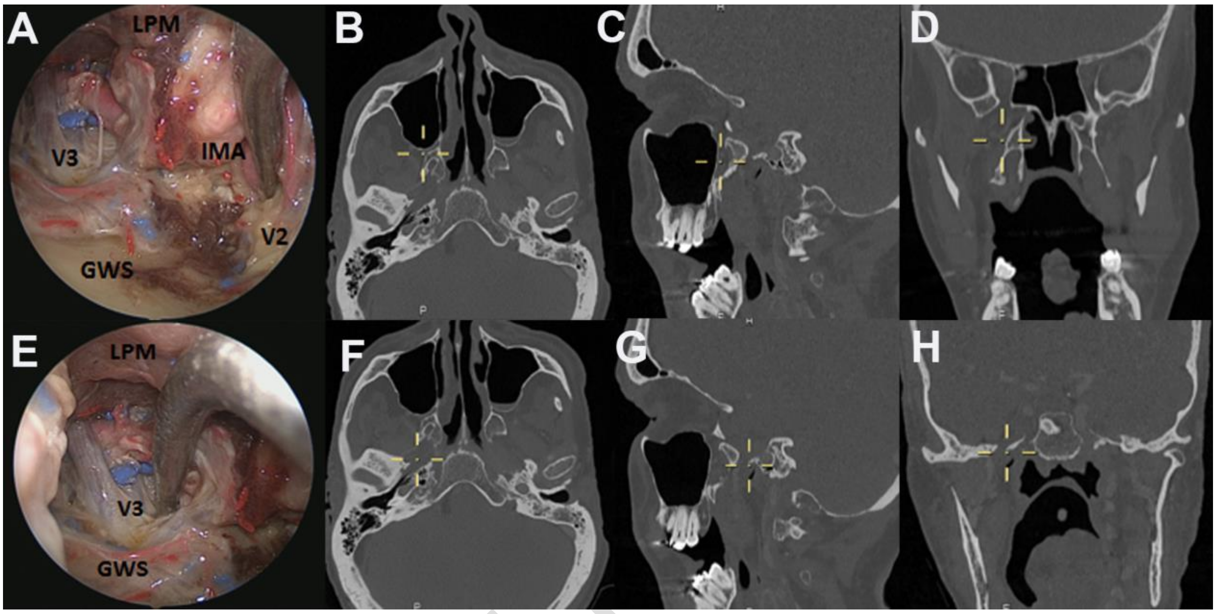

Figure 3: Intra-dissection image guidance screenshots for important surgical landmarks in the infratemporal fossa

Panel A: Screenshot taken while the navigation probe is pointing to the pterygomaxaillary fissure and corresponding neuronavigation screenshots in B: axial, C: sagittal, D: coronal views.

Panel E: Screenshot taken while the navigation probe is pointing to the foramen ovale and corresponding neuronavigation images in F: axial, G: sagittal, H: coronal views.

GWS: greater wing of sphenoid bone; IMA: internal maxillary artery; LPM: lateral pterygoid muscle; V2: maxillary nerve; V3: mandibular nerve.

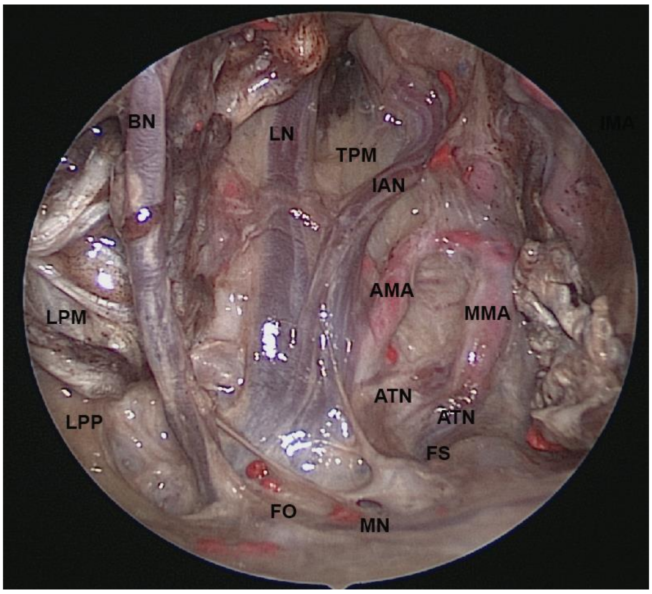

Figure 4: Contents of the posterior infratemporal fossa after resection of the lateral pterygoid muscle (right side)

ATN: auriculotemporal nerve (two roots circling the middle meningeal artery); AMA: accessory meningeal artery; BN: buccal nerve; FO: foramen ovale; FS: foramen spinosum; IAN: inferior alveolar nerve; LN: lingual nerve; LPM: lateral pterygoid muscle; LPP: lateral pterygoid plate; MMA: middle meningeal artery; MN: masseteric nerve; TPM: tensor veli palatini muscle

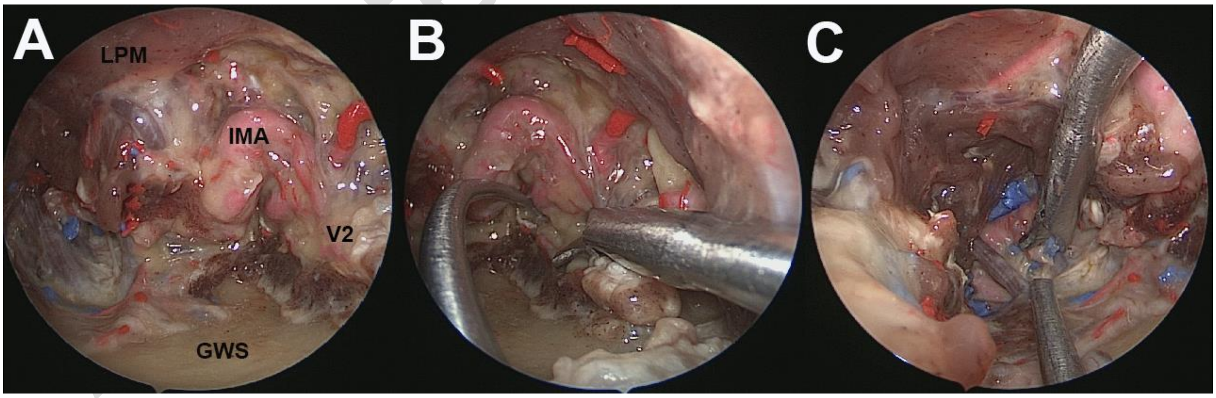

Figure 5: Double port approach to the infratemporal fossa (ITF) (left side)

The endoscope is introduced through the posterior port allowing bimanual dissection through the anterior incision.

Panel A: The surgical view of the ITF from the posterior port; B: Bimanual dissection of the pterygomaxillary fissure; C: Bimanual dissection of the V3

GWS: greater wing of sphenoid bone; IMA: internal maxillary artery; LPM: lateral pterygoid muscle; V2: maxillary nerve

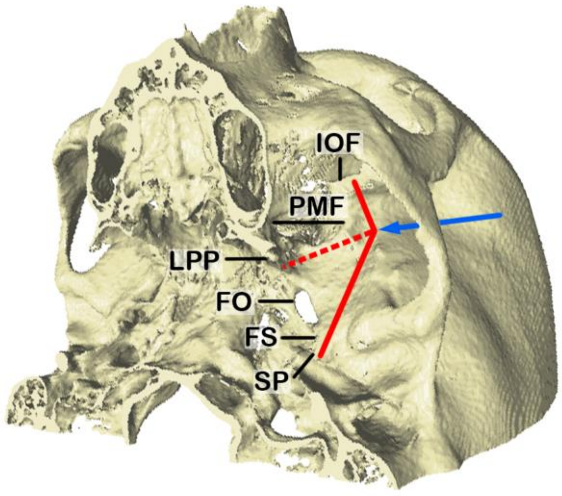

Figure 6: Lateral endoscopic anatomical classification of the infratemporal fossa

The blue arrow represents the direction of the endoscope. The space outlined by the two uninterrupted red lines refers to the area of the exposure yielded by the approach, which is divided by the dotted red line into an anterior and posterior compartment.

FO: foramen ovale; FS: foramen spinosum; IOF: inferior orbital fissure; LPP: lateral pterygoid plate; PMF: pterygomaxillary fissure; SP: spine of sphenoid

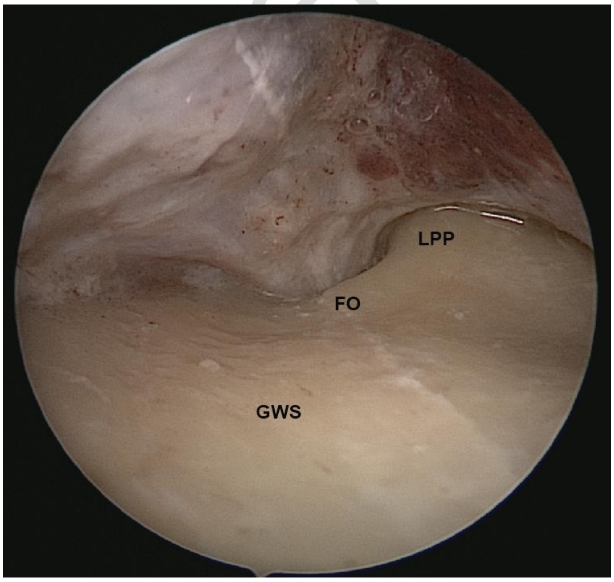

Figure 7: Endoscopic assisted lateral approach to foramen ovale (left side)

Photograph of the foramen ovale after continued uninterrupted subperiosteal dissection of the temporal and the infratemporal fossae.

FO: foramen ovale; GWS: greater wing of sphenoid bone; LPP: lateral pterygoid plate

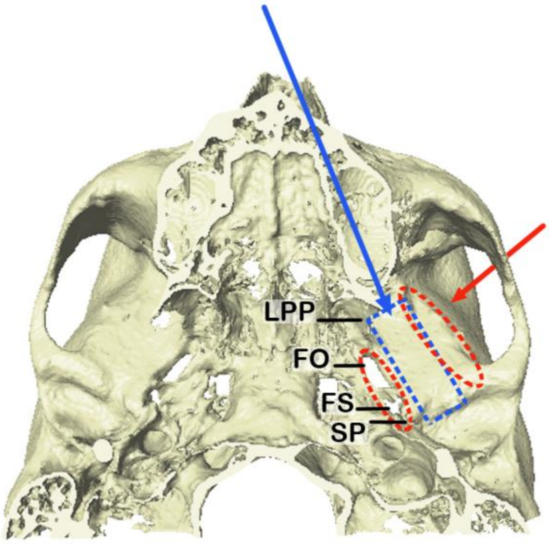

Figure 8: Staged anterior and lateral endoscopic resection of infratemporal fossa lesions (ITF)

The arrows refer to the endoscopic approaches: the blue to the anterior endonasal and the red to the lateral. The area demarcated by the blue color on the undersurface of the greater wing of the sphenoid bone represents to the area easily controlled by an anterior endoscopic access while the two areas posteromedial and far lateral ITF defined by the red color are preferably exposed and managed by a lateral endoscopic access.

FO: foramen ovale; FS: foramen spinosum; LPP: lateral pterygoid plate; SP: spine of sphenoid