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ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Advantages and caveats of endoscopic to the infratemporal fossa as isolated and combined techniques

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Abstract

Objective: Identify the benefits and caveats of combining minimal access approaches to the infratemporal fossa (ITF), such as the endoscopic transnasal, endoscopic transorbital, endoscopic transoral, and endoscopic sublabial transmaxillary approaches to address extensive lesions not amenable to a single approach. The study provides anatomical metrics including area of exposure and degree of surgical freedom.

Methods: Five human cadaveric specimens (10 sides) were dissected to expose and methodically analyze the anatomical intricacies of the ITF using the following minimal access approaches: endoscopic transnasal transpterygoid (EETA), endoscopic sublabial transmaxillary, endoscopic transorbital via infraorbital foramen, and endoscopic transoral techniques. Area of exposure at the pterygopalatine fossa and surgical freedom at the ITF were obtained for each approach.

Results: The endoscopic sublabial transmaxillary sinus and the combined approach afford a significantly greater exposure than an isolated EETA. The difference in exposure (mean) between the endoscopic sublabial transmaxillary and EETA was 1.62 ± 0.85 cm^2 ($p < 0.001$), and the difference between the combined approach and EETA was 4.25 ± 0.85 cm^2 ($p < 0.001$).

Conclusions: Combining minimal access endoscopic approaches to the ITF can provide significantly greater exposure than an isolated EETA; thus, providing enhanced access to address lesions with extensive involvement of the ITF, especially those with superolateral and inferolateral extensions. In addition, some approaches may have an adjunctive role to the resection, such as the endoscopic transoral approach offering the potential for early control of the internal maxillary artery and its branches, some of which may be supplying the tumor in the ITF; or the endoscopic transorbital approach yielding a direct line of sight to the superior ITF and middle cranial fossa.

Level of Evidence: NA.

KEYWORDS

area of exposure, endoscopic surgery, infratemporal fossa, minimally access, multiport approach, surgical freedom

1 | INTRODUCTION

The infratemporal fossa (ITF) is a challenging area to access due to its inward location, combined with a cramped and complex anatomy, that includes vital neurovascular structures. One may find variations in its anatomical description; however, a broadly accepted rendering binds its potential space by the temporal bone and greater wing of the sphenoid bone superiorly; the posterolateral surface of the maxillary sinus anteriorly; the ramus of the mandible laterally; the medial pterygoid and tensor veli palatini muscles medially; and the styloid process and the tympanic part of the temporal bone posteriorly.[1,2] Preformed pathways, including fissures and neurovascular foramina, communicate the ITF with the middle cranial fossa (e.g., foramen spinosum, foramen ovale) as well as with the pterygopalatine fossa (via the pterygomaxillary fissure). Neurovascular structures within the ITF include the internal carotid artery (ICA), internal jugular vein (IJV), cranial nerve (CN) IV-XII, internal maxillary artery (IMA), and pterygoid venous plexus.[1,2] All structures in the ITF can give rise to a neoplasm, or be involved by one that originates and spreads from adjacent structures (e.g., nasopharyngeal cancer, maxillary sinus cancer, meningioma).

A seminal surgical approach to the ITF was described in 1961 by Barbosa, a Brazilian head and neck surgeon, who used it to treat advanced maxillary sinus cancers. Other approaches evolved following various other indications, as well as advances in technology, and techniques.[3] The ITF can be approached from an anterior direction using transfacial transoral, and transnasal approaches; or from a lateral direction, using preauricular and postauricular approaches. Various traditional approaches afford a panoramic exposure that allows the exposure and extirpation of complex lesion in ITF while providing control of the surrounding anatomy. Open traditional approaches, however, bring significant sequelae and may cause inadvertent and undesirable complications including facial nerve palsy, loss of hearing, trismus or instability of the temporomandibular joint, and scars and facial deformity or asymmetry.[4–6]

In recent years, the emergence of novel visualization technologies, customized surgical instruments, high-speed drills, coagulators hemostatic pastes, and surgical navigation devices contributed to the adoption of minimally invasive surgery and, in turn, catapulted the design of innovative endoscopic approach through transnasal, transcranial, transoral and transorbital routes.[7–17] However, minimally invasive approaches generally are limited in the extent of exposure or in their control of neurovascular structures; therefore, limiting their indications to highly selected patients. One of these techniques, the endoscopic transnasal transpterygoid approach (EETA) is excellent to reach and control median anatomical structures and lesions; however, its superior and inferolateral range is limited.[7,8] Conversely, the endoscopic transorbital approach via the inferior orbital fissure (IOF) seems complementary as it afford exposure of the lateral and superior aspects of the ITF.[9] Similarly, an endoscopic transoral approach may access the inferior boundary of ITF, and even reach lesions that extend below the level of the hard palate.[10,11] Other minimal access approaches offer a direct exposure of the ITF (i.e., endoscopic sublabial transmaxillary approach).[12,13] Endoscopic approaches may be used in isolation to yield access to specific areas or, alternatively, they may be combined via multiple portals to provide maximal exposure, to a level that may be comparable or even superior to that of some traditional open techniques.[13–17]

Various minimally invasive endoscopic approaches to the ITF have been described, each providing entry to specific areas. The current study attempts to highlight the benefits of combining the endoscopic transnasal, endoscopic transorbital, endoscopic transoral, and endoscopic sublabial transmaxillary approaches to access the entire ITF while controlling all pertinent neurovascular structures. This affords the potential to expand the indications for minimally invasive techniques, avoiding craniofacial incisions in many patients affected by tumors of the ITF. In addition, we provide a detailed and quantitative endoscopic anatomical description of the exposure and ease of instrumentation achieved with these combined approaches. This objective data will spotlight the benefits of the combined over the isolated approaches.

2 | MATERIALS AND METHODS

ITF dissections proceeded in five adult (10 sides), cadaveric specimens, prepared with intravascular injections of red- and blue-colored, latex-injected specimens via an EETA, endoscopic sublabial transmaxillary approach, endoscopic transorbital approach via IOF, and endoscopic transoral approach. Dissections were conducted at the Anatomy Laboratory Toward Visuospatial Surgical Innovations in Otolaryngology and Neurosurgery (ALT-VISION) of the Wexner Medical center of The Ohio State University by a faculty-level skull base surgeon (KM) following standardized methods (described to follow). All surgical approaches were performed under direct endoscopic visualization, with the assistance of 0°, 30°, and 45° rod-lens endoscopes coupled to a high-definition camera and monitor (Storz Endoscopy, Tuttlingen, Germany).

Endoscopic and powered instruments including micro-debriders and MidasRex stylus electric drills (Medtronic, Jacksonville; FL) were used to complete the appropriate steps of each procedure. A Stryker navigational system (Kalamazoo, MI) was loaded with the digital imaging and communications in medicine data from high-resolution CT scans that were performed before the dissections.

An AIDA system (Karl Storz Endoscopy, Tuttlingen, Germany) was used to video-record (MPEG 2 format) and capture images (TIF format) of the dissections. These were used to define and document the anatomic relationships of the endoscopic anatomy, correlated with the multiplanar CT views provided by the image guidance system.

2.1 | Surgical procedure

Endoscopic transnasal transpterygoid, endoscopic sublabial transmaxillary, endoscopic transorbital via IOF, and endoscopic transoral approaches were respectively performed following previously described techniques.[9,11–13,18–20] *Area of exposure* was measured upon reaching the pterygopalatine fossa; whereas *surgical freedom* was measured after the entire ITF was dissected. The method for establishing the *area of exposure* and *surgical freedom* has been reported in detail previously.[19,21]

Laryngoscope Investigative Otolaryngology

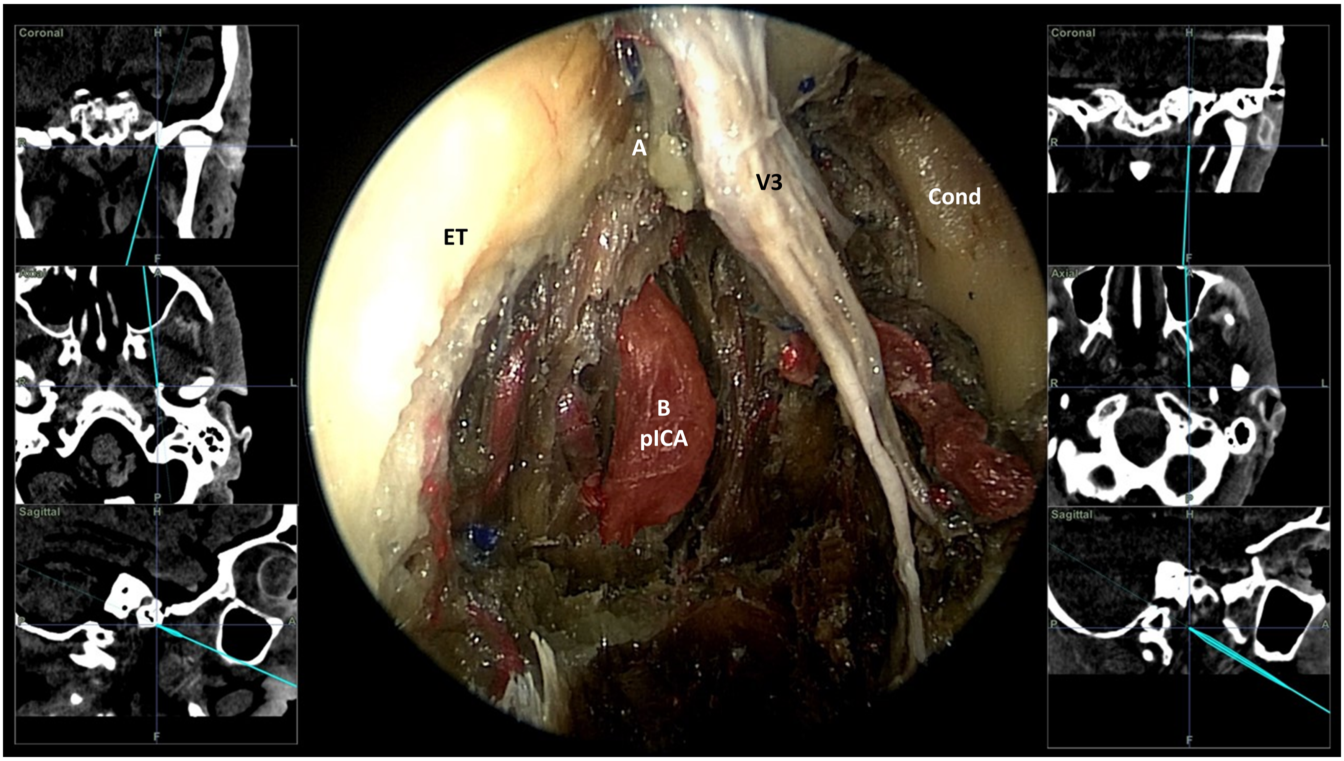

FIGURE 1 Endoscopic visualization with 0° rod-lens endoscope demonstrating a left transnasal transpterygoid approach to the infratemporal fossa. Photographs on the right correspond to the bony-cartilaginous Eustachian tube junction or point "A." Multiplanar images on the left represent point "B" which is the parapharyngeal carotid artery. ET = Eustachian tube; pICA = parapharyngeal carotid artery; V3 = mandibular division of trigeminal nerve; Cond = mandibular condyle.

2.2 | Endoscopic transnasal transpterygoid approach

This technique started with a nasal corridor that included the removal of the ipsilateral of the middle turbinate, an uncinectomy, a total ethmoidectomy, and the widest possible sphenoidotomy. Then, the inferior turbinate and lateral wall of the nose were removed (i.e., medial maxillectomy) to expose the entire posterior wall of the maxillary sinus. The mucosa over the posterior wall of the maxillary sinus was removed and the ethmoidal crest and sphenopalatine foramen were identified. Removal of the posterior wall of the antrum and the ascending process of the palatine bone with Kerrison's rongeurs started at the sphenopalatine foramen, following the proximal SPA and posterior nasal artery retrograde to reach the IMA. Exposure of the posterior neural compartment of the pterygopalatine fossa, identifying the infraorbital, vidian, and descending palatine nerves, as well as the pterygopalatine ganglion with its connections to the aforementioned nerves. The vidian canal and foramen rotundum were identified at the anterior aspect of the pterygoid process and the pterygoid bone was drilled progressively around the vidian canal and following the maxillary division of the trigeminal nerve (V2) from the foramen rotundum to the medial of the dura of the middle cranial fossa. Once the medial pterygoid process and plate were removed, the tensor and levator veli palatini are identified at the anterior and inferior aspect of the eustachian tube respectively. The foramen ovale is anterior to the cartilaginous eustachian tube and lateral to the vidian nerve and the anterior genu of the ICA. The parapharyngeal segment of the ICA is posterior to the eustachian tube (Figure 1).

2.3 | Endoscopic sublabial transmaxillary approach

A horizontal incision over the maxillary aspect of the gingivobuccal sulcus was carried through the periosteum of the maxilla. This allowed the dissection of the facial soft tissues following a nearly avascular subperiosteal plane, and exposing the anterior maxilla including the infraorbital nerve which marked the superior boundary of the approach. A 1.5 × 1.5 cm opening in the anterior maxilla was completed with chisel and mallet or the high-speed drill, and the sinus mucosa was peeled away. A transmaxillary approach, through the posterior wall of the antrum, sinus afforded the most direct corridor to the pterygopalatine or ITF.

2.4 | Endoscopic transorbital approach via the infraorbital foramen

An inferior eyelid incision placed subtarsal or following a skin crease, was carried through the periorbita between the orbicularis oculi muscle and the orbital septum to facilitate a subperiorbital dissection from the bones of the orbit. Following identification of the inferior orbital

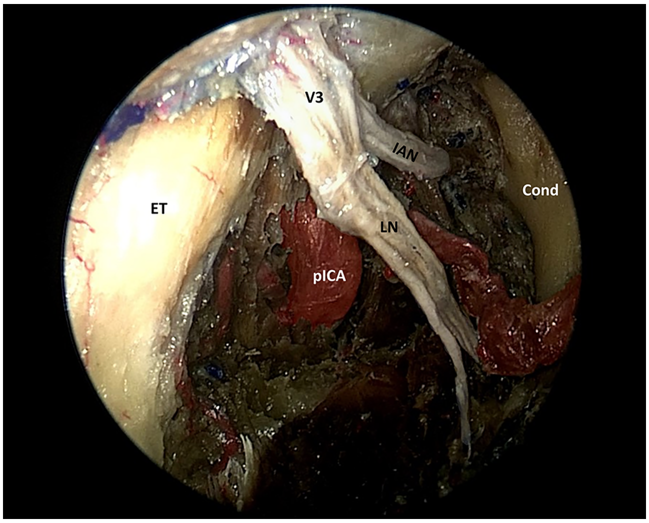

FIGURE 2 Endoscopic visualization with 30° rod-lens endoscope demonstrating a left endoscopic-assisted transorbital approach to the left infratemporal fossa. ET = eustachian tube; pICA = parapharyngeal carotid artery; V3 = mandibular division of trigeminal nerve; IAN = inferior alveolar nerve; LN = lingual nerve; Cond = Mandibular condyle.

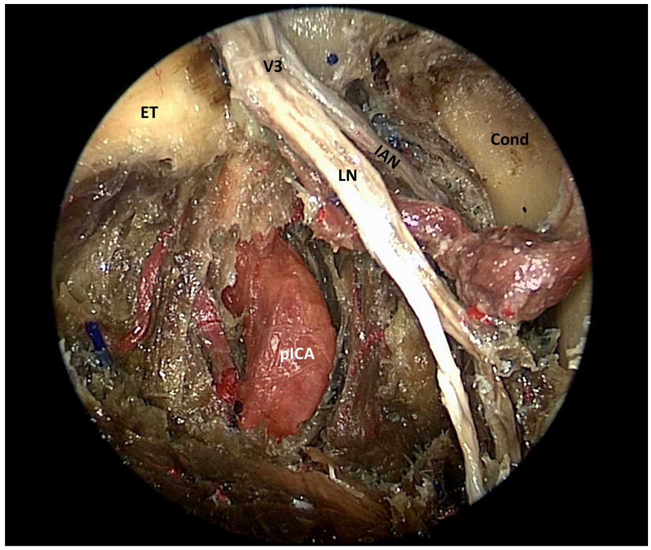

FIGURE 3 Endoscopic visualization with 30° rod-lens endoscopic demonstrating a left endoscopic-assisted transoral approach to left infratemporal fossa. ET = eustachian tube; pICA = parapharyngeal carotid artery; V3 = mandibular division of trigeminal nerve; IAN = inferior alveolar nerve; LN = lingual nerve; Cond = Mandibular condyle.

fissure (IOF), the lateral orbital wall was drilled out exposing the temporalis muscle and providing additional working space. Using a high-speed drill, the orbital wall corresponding to the greater wing just was removed starting with the area that is posterior to the IOF and continuing to access the mid and posteromedial aspects of the IOF, eventually reaching the middle cranial fossa. Landmarks such as the foramen ovale, foramen spinosum, and sphenoid spine were identified at the roof of the ITF. Foramen rotundum and the lateral pterygoid plate were identified as the dissection continued in a medial. Of note, the dissection was mostly performed subperiosteally leaving the ITF contents in a periosteal sac; thus, requiring opening and removing this layer in order to expose the soft tissues of the ITF. Transection of the superior head of the lateral pterygoid muscle (LPM) was needed for a more complete exposure (Figure 2).

2.5 | Endoscopic transoral approach

An incision was carried through the mucosa following the trajectory of the ascending ramus of the mandible and extending to reach the maxillary tuberosity. This served to expose the entire length of the medial pterygoid muscle (MPM) from its origin at the posterior and medial lateral pterygoid plate to is insertion at the angle of the mandible. The buccal fat pad often herniates during this step; thus, requiring its lateral displacement and bipolar cauterization. The inferior alveolar nerve (IAN) can be identified following the medial retraction of the MPM and can be traced proximally to identify the medially located lingual nerve. Proximal dissection of the inferior alveolar and lingual nerves leads to the foramen ovale and eventually the Gasserian ganglion. Proximal dissection of the IAN will necessarily encounter the lower head of the LPM, arising at the lateral aspect of the lateral pterygoid plate and running horizontally to insert at the mandibular condyle. One should note that the lower head of the LPM corresponds to the level at which the IAN branches out of V3 at the foramen ovale. As aforementioned, the transection or removal of the LPM reveals the roof of the ITF; thus, helping to expose the foramen spinosum (posterolateral to the foramen ovale) and the control of the middle meningeal artery. The parapharyngeal segment of the ICA is located posterior to the foramen ovale and eustachian tube (Figure 3).

3 | MEASUREMENTS

3.1 | Area of exposure

Area of exposure was calculated using three fixed and two variable points. The three fixed points included the vidian canal, the proximal end of infraorbital canal, and the entry of the greater palatine neurovascular bundle into the hard palate. Two variable points of reference included the lateral-most areas superiorly and inferiorly. The stereotactic probe was used to determine the correlation of these points in the three dimensions. Screen captures from the image guidance system were used to measure the area of exposure. The total exposure area was calculated by computer as the sum of the area of three triangles formed by joining the ends (Figure 4).

3.2 | Surgical freedom

Surgical freedom was defined as the maximal oval area along which the proximal end of the endoscope can be freely and easily moved with

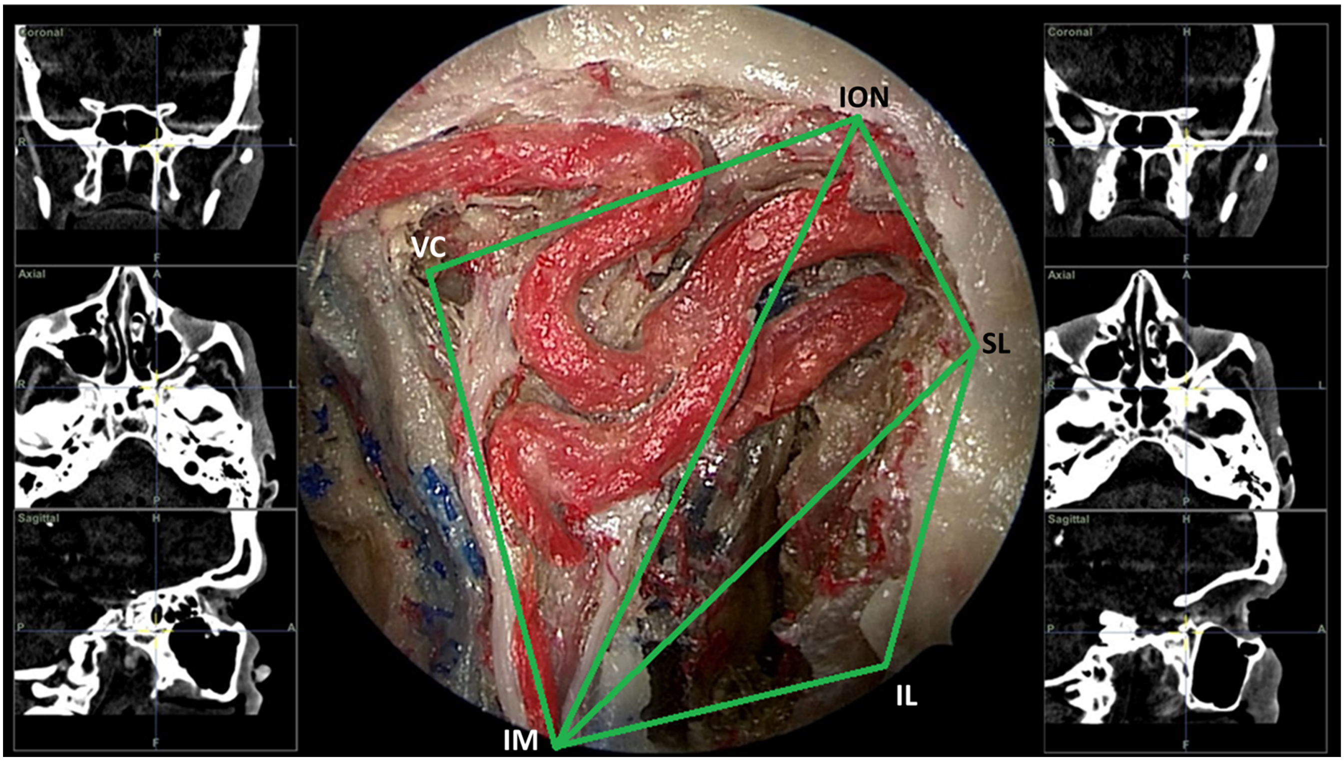

FIGURE 4 Endoscopic visualization with 0° rod-lens endoscope left transnasal demonstrating of the posterior wall of the maxilla illustrating the area of exposure. The fixed points used for computing the area are vidian canal (VC), infraorbital nerve (ION) at the proximal end of the canal, The most inferomedial point which is the junction of the greater palatine neurovascular bundle with the hard palate (IM), and the variable points are the most superolateral point of bone removal (SL) and the most inferolateral point of bone removal (IL). Multiplanar images on the right represent vidian canal. Multiplanar images on the left represent foramen rotundum.

the distal end of the instrument fixed on a specific target of interest. Set targets for computing surgical freedom included the vidian canal, foramen rotundum, foramen ovale, and the mandibular condyle superolateral aspect. Using stereotactic navigation, while the distal end of an endoscopic instrument (3-mm dissector, 22 cm in length) was kept fixed on target, the proximal end of the instrument was moved in the horizontal axis from the most anatomical right to the most anatomical left. This movement provided the horizontal diameter. In a similar fashion, the vertical diameter can be recorded by move the proximal end of the instrument in the vertical axis from the most superior to the most inferior area. The oval area was calculated using the horizontal and vertical radius by computer. The formula for calculating area is $A = \pi ab$, where a is the radius of the major axis and b is the radius of the minor axis.

3.3 | Statistical analysis

The *area of exposure* and *surgical freedom* were compared among the combined approaches (endoscopic transnasal transpterygoid, endoscopic transorbital via IOF, and endoscopic transoral approach) and the endoscopic sublabial-transmaxillary approach and EETA. We calculated the paired *t-test* (Excel, Microsoft, Inc., Redmond, Washington, United States). A *p-value* <0.05 was considered statistically significant.

4 | RESULTS

4.1 | Area of exposure

The average *area of exposure* provided by each approach is shown in Table 1.

The multi-corridor approach combining the endoscopic transnasal transpterygoid with an endoscopic transorbital and an endoscopic transoral approaches provided the largest area of exposure, followed by the endoscopic sublabial transmaxillary and transnasal transpterygoid approaches, respectively. The endoscopic sublabial-transmaxillary and the multi-corridor approach can significantly increase exposure compared to an isolated EETA. The mean difference of exposure between the endoscopic sublabial transmaxillary and the EETA was 1.62 ± 0.85 cm^2 (p < 0.001). The mean difference of exposure between the multi-corridor approach and the EETA was 4.25 ± 0.85 cm^2 (p < 0.001).

4.2 | Surgical freedom

The mean surgical area for each of the approaches at the fixed target points is shown in Tables 2 and 3.

The endoscopic sublabial transmaxillary approach afforded significantly greater *surgical freedom* than the EETA on both fixed points.

	EETA	Sublabial transmaxillary	Combined
Area of exposure (cm^2)	4.40 ± 0.86	6.11 ± 1.02	8.75 ± 1.40

TABLE 1 The average *area of exposure* provided by each approach.

TABLE 2 The mean surgical area for each of the approaches at the fixed target points.

Surgical freedom (cm^2)	Vidian canal	Foramen rotundum
EETA	1.10 ± 0.37	0.79 ± 0.34
Sublabial transmaxillary	2.03 ± 0.87	3.25 ± 1.23

TABLE 3 The mean surgical area for each of the approaches at the fixed target points.

Surgical freedom (cm^2)	Foramen ovale	Mandibular condyle
Transorbital	1.57 ± 0.74	0.94 ± 0.41
Transoral	1.40 ± 0.55	4.18 ± 1.18

The mean difference in *surgical freedom* was 0.93 ± 0.96 cm^2 ($p = 0.01$) and 2.45 ± 1.21 cm^2 ($p < 0.001$) on the vidian canal and foramen rotundum, respectively.

The endoscopic transorbital approach provided less *surgical freedom* than the endoscopic transoral approach at the level of the foramen ovale. The mean difference in *surgical freedom* was 0.17 ± 1.07 cm^2 ($p = 0.64$). Conversely, the endoscopic transoral approach significantly provided greater *surgical freedom* than the endoscopic transorbital approach at the level of the mandibular condyle. The mean difference in surgical freedom was 3.24 ± 1.00 cm^2 ($p < 0.001$).

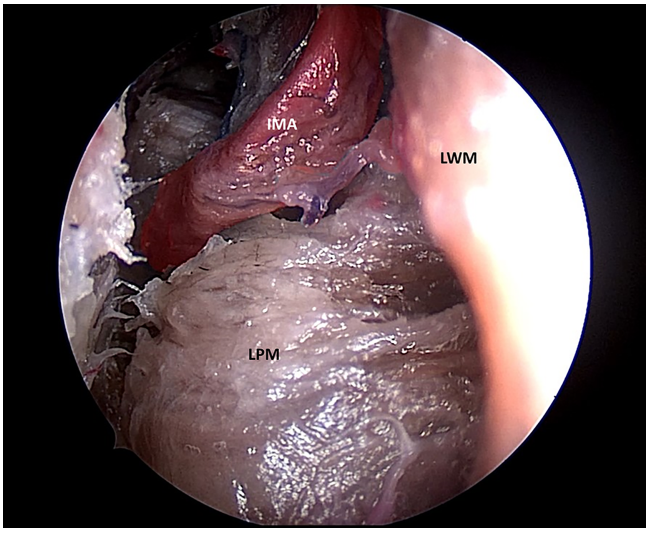

FIGURE 5 Endoscopic visualization with 30° rod-lens endoscope demonstrating a right endoscopic-assisted transoral approach to the right oral cavity highlighting the relationship between the internal maxillary artery (IMA) and the pterygoid muscle. LWM = lateral wall of maxillary sinus; LPM = lateral pterygoid muscle.

5 | DISCUSSION

This study describes the combination of minimally invasive surgical techniques to access the entire ITF affording the benefits of each technique while decreasing their limitations. The study quantitatively demonstrates the *areas of exposure* and *surgical freedom* of the respective techniques. The result confirmed the feasibility to control the ITF using multi-corridor combined approaches that provide the greatest area of exposure.

Others have suggested findings that were confirmed in the current study. Youssef et al. suggested that the EETA yields superior access to structures closer to midline (e.g., sella turcica, clivus, nasopharynx) and seems appropriate to control the pterygopalatine fossa.[22] Conversely, Ong et al.[12] demonstrated the safe and direct corridor to the middle cranial fossa furnished by an endoscopic sublabial transmaxillary approach.The current study suggests other benefits associated with an endoscopic sublabial transmaxillary approach such as providing a greater *exposure area* and *surgical freedom* than an EETA.

An endoscopic transorbital approach to the ITF was reported by Gerges et al. These authors suggested that the approach is safe, and provides adequate space drilling, instrumentation, and control of the ITF and middle cranial fossa. However, it fails to access the posterior and inferior aspects of ITF.[9] In the current study, the transorbital approach provided a direct angle of attack to the superolateral of the ITF. Combined with an EETA, a transorbital approach can tackle lesions that involves the entire ITF roof or lesions that invade the middle cranial fossa.

An endoscopic transoral approach to the ITF was first described by Chan et al. and subsequently elaborated by Patwa et al. as a potential direct corridor to the ITF. However, one should note that the approach provides a narrow working corridor and limited access to the pterygopalatine fossa.[11,20] The transoral approach is a valuable adjunct for multi-corridor surgery providing complementary exposure that extends caudally to the level of the hard palate and as lateral as the mandible. In addition, it offers the potential to control the internal maxillary artery early during the approach (Figure 5).

The combination and ordinal preference for these approaches will vary according to the surgical strategy. For example, a lesion mainly supplied by the internal maxillary artery may be first approached with an endoscopic transoral technique to decrease intraoperative bleeding. An endoscopic transorbital approach should be subsequent to an EETA when a lesion extends to the cephalad aspect of the ITF or invades the middle cranial fossa. An endoscopic sublabial transmaxillary approach serves as an adjunctive instruments port with the endoscope transnasal transpterygoid approach when it needs a different angle or more surgical freedom for dissection.

Laryngoscope Investigative Otolaryngology

The current study suggests clear benefits to combining all approaches; thus expanding the indications for minimally invasive techniques by affording access to all regions in the ITF, providing multiple angles of attack; therefore extending the indication of minimally invasive surgery for select complex lesions. Each approach, however, showed advantages in different areas that need to be consider. The main limitation of the combined approaches is the difficulty of dealing with the lesion that invades surrounding bones such as the mandible or hard palate. Conventional open surgery might be superior in this situation.

6 | CONCLUSION

Combining the endoscopic transnasal, endoscopic transorbital, endoscopic transoral, and endoscopic sublabial transmaxillary approaches allows access to the entire ITF while controlling all pertinent neurovascular structures. This affords the potential to expand the indications for minimally invasive techniques, avoiding craniofacial incisions in many patients affected by tumors of the ITF.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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