Effect of Incremental Endoscopic Maxillectomy on Surgical Exposure of the Pterygopalatine and Infratemporal Fossae

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Abstract

Objective Access to the pterygopalatine and infratemporal fossae presents a significant surgical challenge, owing to their deep-seated location and complex neurovascular anatomy. This study elucidates the benefits of incremental medial maxillectomies to access this region. We compared access to the medial aspect of the infratemporal fossa provided by medial maxillectomy, anteriorly extended medial maxillectomy, endoscopic Denker approach (i.e., Sturmann-Canfield approach), contralateral transseptal approach, and the sublabial anterior maxillotomy (SAM).

Methods We studied 10 cadaveric specimens (20 sides) dissecting the pterygopalatine and infratemporal fossae bilaterally. Radius of access was calculated using a navigation probe aligned with the endoscopic line of sight. Area of exposure was calculated as the area removed from the posterior wall of maxillary sinus. Surgical freedom was calculated by computing the working area at the proximal end of the instrument with the distal end fixed at a target.

Results The endoscopic Denker approach offered a superior area of exposure ($8.46 \pm 1.56 \text{ cm}^2$) and superior surgical freedom. Degree of lateral access with the SAM approach was similar to that of the Denker.

Conclusion Our study suggests that an anterior extension of the medial maxillectomy or a cross-court approach increases both the area of exposure and surgical freedom. Further increases can be seen upon progression to a Denker approach.

Keywords

- infratemporal fossa
- endoscopic
- medial maxillectomy
- transseptal
- endoscopic Denker
- surgical freedom

Introduction

Endoscopic endonasal surgery triggered a paradigm shift in our approach to skull base lesions. An upsurge in experience and a better understanding of the endoscopic anatomy of the region have widened the indications for this technique systematically and progressively. This is exemplified by the

evolution and progression of endonasal endoscopic approaches from the median to the paramedian skull base. Regardless of the method of visualization, surgical access to deep-seated regions with a dense neurovascular anatomy, such as the pterygopalatine and the infratemporal fossae, remains a challenging endeavor. As with any other surgical approach, adequate visualization and ease of instrument

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maneuverability are of paramount importance for the safe and successful resection of lesions in this complex area.

Various approaches to the infratemporal fossa were previously described.¹⁻³ Open approaches offer excellent exposure and remain an important component of the skull base surgeon's armamentarium; however, they are associated with a high incidence of cranial nerve dysfunction, wound healing problems, hearing disability, and trismus.^{4,5} These caveats have heightened the interest in exploring endoscopic approaches to this region, taking advantage of the natural air spaces of the sinonasal corridor to decrease some of the inherent morbidities of open procedures (►Fig. 1a, b).

This study attempts to elucidate the benefits of incremental maxillectomies on the exposure of the infratemporal fossa. Although the benefits and drawbacks of the endoscopic Denker approach (i.e., endoscopic Sturmann-Canfield approach) have been broached by others, a literature search did not reveal any objective data regarding the gains in this regard.⁶⁻¹⁰ To our knowledge, this is the first study to yield objective data regarding the additional visualization and instrumentation obtained with an endoscopic Denker approach.

Material and Methods

We studied 10 cadaveric specimens dissecting the pterygopalatine and infratemporal fossae bilaterally (20 sides). All dissections were performed in accordance with institutional protocols at the Anatomical Laboratory toward Visuospatial

Innovations in Otolaryngology and Neurosurgery at the Wexner Medical Center of The Ohio State University. All specimens underwent a high-resolution computed tomography (CT) scan, and the data set was imported to a Stryker surgical navigation system (Stryker Navigation, Kalamazoo, Michigan, United States). To standardize the measurements, only straight instruments and a 0-degree rod lens endoscope were used (Karl Storz Endoscopy, Tuttlingen, Germany).

Removal of the middle turbinate and bilateral anterior and posterior ethmoidectomies widened the nasal corridor. The inferior turbinate was subsequently resected, and pertinent dissections were performed in five progressive stages, documenting radial access, area of exposure, and surgical freedom at each stage.

Surgical Stages

Stage I: Endoscopic Medial Maxillectomy

The first stage included a medial maxillectomy (MM) extending from the floor of the orbit superiorly, to the floor of the nasal cavity inferiorly; and from the nasolacrimal duct anteriorly to the sphenopalatine foramen and descending palatine canal posteriorly. The sphenopalatine artery is identified, and the bone removal begins from the anterior wall of the sphenopalatine foramen in a medial to lateral direction resulting in the removal of the posterior wall of the maxillary sinus. Further dissection of the infratemporal fossa was done in accordance with the technique described by Falcon et al¹¹ (►Fig. 2a, b).

Fig. 1 Photographs illustrating the osseous anatomy of the lateral nasal wall. (A) Sagittal section of the lateral wall of the nose. The lateral wall of the nose is mainly formed by the maxilla. The other bones that contribute in forming the lateral wall anteriorly include the nasal bone, frontal bones, and lacrimal bones. Posteriorly the maxilla articulates with the perpendicular plate of the palatine bone that in turn articulates with the pterygoid process of the sphenoid bone. Superiorly the ethmoidal labyrinth completes the lateral wall of the nose. The inferior nasal also contributes to the formation of the lateral nasal wall (blue dotted line marks the position of the inferior concha). (B) Photograph showing the maxilla (medial view) with articulation of the palatine bone. The frontal process of maxilla articulates with the frontal bone superiorly. The anterior portion of the maxilla has the lacrimal groove that is covered by the lacrimal bone to form the channel for the nasolacrimal duct. The palatine process of the maxilla posteriorly articulates with the horizontal plate of the palatine bone to form the hard palate. The orbital process and the sphenoidal processes of the palatine bone are separated by a notch (i.e., sphenopalatine notch marked by a white asterisk) that is converted into a foramen by the undersurface of the body of sphenoid. ANS, anterior nasal spine; AP, alveolar process; FB, frontal bone; FPM, frontal process of maxilla; FS, frontal sinus; HP, hard palate; LG, lacrimal gland fossa and duct; MS, maxillary sinus; NB, nasal bone; OP, orbital process; PB, palatine bone vertical process; PP, pterygoid process of the palatine bone; SP, sphenoid process; SPF, sphenopalatine foramen; SS, sphenoid sinus; orange dotted line marks the position of the nasolacrimal duct (N) in the lacrimal groove.

Fig. 2 Endoscopic endonasal cadaveric dissection illustrating the surgical approaches and the extent of lateral wall resections, respectively. (A) Endoscopic image showing a left medial maxillectomy, extending from nasolacrimal duct anteriorly to the sphenopalatine foramen and greater palatine vessels posteriorly, and from floor of orbit superiorly to the floor of the nasal cavity inferiorly. The orange line marks the position of the nasolacrimal duct, which is the anterior most limit of the dissection. (B) Photograph of the lateral nasal wall illustrating the extent of bony resection in an endoscopic medial maxillectomy. (C) Endoscopic endonasal cadaveric dissection showing the anteriorly extended medial maxillectomy approach (left). The nasolacrimal duct (N) is identified and sharply transected. The maxillectomy is extended anteriorly to reach the pyriform aperture using back biting instruments. (D) Photograph of the lateral nasal wall showing the extent of bony resection in an anteriorly extended medial maxillectomy. F, floor of the nasal cavity; FPM, frontal process of maxilla; FS, frontal sinus; PWM, posterior wall of the maxilla; R, roof of maxillary sinus; SPF, sphenopalatine foramen.

Stage II: Anteriorly Extended Medial Maxillectomy

The medial maxillectomy was extended anteriorly (EMM) to reach the pyriform aperture. In the process, the nasolacrimal duct was identified, dissected off its canal, and sharply transected. The bone of the anterior aspect of the medial wall of the maxilla was removed using back biting instruments extending the MM anteriorly until encountering the thick bone of the pyriform aperture (► **Fig. 2c, d**).

Stage III: Transseptal Approach

A transseptal approach was incorporated to document the additional exposure gained from a “cross-court” angle. A posterior septectomy was done after transfixing the bony cartilaginous junction. Care was taken to leave sufficient cartilaginous septum anteriorly and to make sure it would be well supported on the maxillary crest and would support the nasal pyramid.

Stage IV: Endoscopic-Assisted Denker Approach

The EMM was expanded further with the addition of an endoscopic Denker approach (i.e., Sturmman-Canfield approach). The lateral edge of the piriform aperture was identified by palpation, just anterior to the inferior turbinate, so

that the overlying mucosa and periosteum could be incised vertically, thus exposing the pyriform crest. Soft tissue elevation, following a subperiosteal plane, exposed the anterior wall of the maxilla identifying and preserving the infraorbital nerve. Using a high-speed drill, the piriform aperture (ascending process of the maxilla) and anterior wall of the maxilla were removed laterally to reach the level of the infraorbital nerve (arbitrary point chosen to standardize the maxillotomy) (► **Fig. 3**).

Stage V: Endoscopic-Assisted Sublabial Anterior Maxillotomy

A sublabial anterior maxillotomy, often misnamed as a Caldwell-Luc approach, has been extensively studied in the literature and serves as a standard for comparison; thus we performed this approach on the contralateral side in all specimens.^{6,8,12} A gingivobuccal incision was made, and the soft tissues of the cheek were elevated exposing the infraorbital nerve. A maxillotomy of approximate dimensions 1.5 × 1.5 cm was created in the anterior wall of the antrum, inferior to the infraorbital nerve. The maxillotomy was standardized for the purpose of uniformity during the study. It is understood that a smaller or larger maxillotomy could lead to

Fig. 3 Cadaveric dissection demonstrating the endoscopic Denker approach (0-degree endoscope) and photograph illustrating the extent of bony resection. (A) The anterior wall of the maxilla is exposed after the subperiosteal elevation of soft tissues following a vertical incision anterior to the inferior turbinate. The infraorbital nerve is identified. (B) Pyriform aperture (frontal process of maxilla) and the anterior wall of the maxilla are removed using a high-speed drill. An imaginary vertical line intersecting the lateral aspect of the infraorbital foramen represents the limit of bone removal laterally. (C) Frontal view of the skull showing the extent of bony resection in an endoscopic Denker approach. We chose the infraorbital foramen as the lateral limit for bony resection in all cadavers to standardize the maxillotomy. However, during a clinical scenario, the bony resection can be extended further laterally. (D) Photograph of the lateral nasal wall showing the extent of bony resection in an endoscopic Denker approach. ANS, anterior nasal spine; APM, alveolar process of maxilla; ASAN, anterior superior alveolar nerve; AWM, anterior wall of the maxilla; FPM, frontal process of maxilla; ION, infraorbital nerve; IT, inferior turbinate; N, nasolacrimal duct; PWM, posterior wall of maxilla; S, septum; SPF, sphenopalatine foramen; ZB, zygomatic bone; ZPM, zygomatic process of maxilla.

a greater limitation or expansion of the approach; however, we chose our boundaries to standardize the opening and to be able to compare our results with previous publications.^{8,12,13} Further endoscopic dissection was done through this maxillotomy.

Radius of Surgical Access

Maximum radius of surgical access was calculated placing the stereotactic probe in alignment with the endoscopic line of sight. The angle of maximum endoscopic excursion with each of the approaches was documented as screenshots. The angles were measured from midline to the most anterolateral point accessed by a straight probe (→ Fig. 4a–c).

Area of Exposure

Area of exposure was calculated as the area of bone removed from the posterior wall of the maxillary sinus. To calculate the area, three fixed and two variable points were used. The three fixed points included the vidian canal, the infraorbital nerve at the proximal end of the canal, and the inferior point (IP)

defined as the junction of greater palatine neurovascular bundle with the hard palate. Two variable points of reference included the lateral-most limit of bone removal superiorly and the lateral-most limit of bone removal inferiorly. The stereotactic probe was used to determine the coordinates of these points in the three dimensions. The total area of exposure was calculated as the sum of the area of the three triangles formed by joining the points (→ Fig. 4d).

Surgical Freedom

Surgical freedom was calculated using stereotactic navigation by computing the working area at the proximal end of an instrument (i.e., nostril/pyriform aperture) with the distal end of the instrument fixed on a specific target of interest. Fixed targets used for computing surgical freedom in the axial plane included the vidian canal, foramen ovale, and the superolateral aspect of the mandibular condyle. Targets in the coronal plane included the foramen rotundum and an arbitrary IP as defined earlier. Keeping the distal end fixed on the target, the proximal end of the instrument was moved in

Fig. 4 Photographs illustrating the various parameters used for comparison of the surgical approaches (A) Degree of radial access (documented as screenshots using the stereotactic probe (green line) placed in alignment with the endoscopic line of sight. (B) Angles are measured from the midline (blue line). (C) Computed tomography scan (axial view) representing the radial access obtained with medial maxillectomy (red line), anteriorly extended medial maxillectomy (green line), and endoscopic Denker approach (purple line). The nasolacrimal duct is the limiting factor in a medial maxillectomy, whereas the thick hard bone of the pyriform aperture becomes the limiting factor in an anteriorly extended medial maxillectomy. (D) Endoscopic cadaveric dissection of the posterior wall of the maxilla illustrating the area of exposure (measured as area of bone removal from the posterior wall of maxilla). The fixed points used for computing the area are vidian canal (VC), infraorbital nerve (ION) at the proximal end of the canal, IP (defined as the junction of the greater palatine neurovascular bundle with the hard palate), and the variable points are SL and IL (respectively defined as the lateral-most extent of bone removal superiorly and inferiorly). The total area is calculated as the sum of the area of the three triangles formed by joining these points. (E) Cadaveric dissection using a 0-degrees endoscope showing the target points used for computing the surgical freedom, VC, and inferior point (IP) in the vertical plane and foramen rotundum (FR), foramen ovale (FO), and mandibular condyle (MC) in the horizontal plane. (F) Photograph demonstrating the use of surgical navigation to compute the surgical freedom. The stereotactic probe is placed on the proximal end of the instrument (nostril); the distal end is fixed at a specific target. Keeping the distal end fixed on the target, the proximal end is moved in the four extreme cardinal positions (superior, inferior, anatomical right, and anatomical left). The stereotactic probe at the proximal end of the instrument records the coordinates in the positions just mentioned. Final area is calculated as the sum of the area of triangles formed by joining these points.

the four extreme cardinal points: superior, inferior, anatomical right, and anatomical left. The working area was calculated using the three-dimensional coordinates obtained at the four extreme positions^{8,14} (►Fig. 4e and 4f).

Statistical Analysis

All parameters (radial access, area of exposure and surgical freedom) were compared among all the approaches sequentially using the *t* test (Graph Pad Quick Calcs, Graph Pad Software, Inc., La Jolla, California, United States). A *p* value < 0.05 was considered statistically significant.

Results

Radial Access

The extent of lateral access increased significantly with the addition of an MM (30 ± 3.62 degrees), EMM (40 ± 2.34 degrees), and contralateral transseptal approach (48 ± 4.52 degrees). Adding a Denker approach further increased the lateral access (53.14 ± 4.67 degrees); however, this additional

increase was not statistically significant when compared with the increase provided by the addition of a contralateral transseptal approach. The endoscopic-assisted sublabial anterior maxillotomy (53.42 ± 3.99 degrees) provided a similar radial access to that of the Denker approach.

Area of Exposure

Area of exposure provided by an MM (4.79 ± 1.42 cm²) was significantly smaller than the areas exposed by the EMM, contralateral transseptal, Denker, and sublabial anterior maxillotomy approaches (6.74 ± 1.12 cm², 7.07 ± 1.38 cm², 8.46 ± 1.56 cm², and 7.97 ± 1.71 cm², respectively; *p* < 0.05).

Surgical Freedom

The endoscopic Denker approach offered the highest surgical freedom at all the target points followed by the sublabial anterior maxillotomy approach. In one of the cadavers it was not possible to reach the mandibular condyle using only an MM approach (►Fig. 5; ►Table 1).

Fig. 5 Graph showing mean surgical freedom (in centimeters squared) for each of the approaches at the fixed target points. EMM, extended medial maxillectomy; FO, foramen ovale; FR, foramen rotundum; IP, inferior point (defined as the junction of greater palatine neurovascular bundle with the hard palate); MC, mandibular condyle; MM, medial maxillectomy; SAM, sublabial anterior maxillotomy; SF, surgical freedom; VC, vidian canal.

Table 1 Analysis of surgical freedom at foramen rotundum, foramen ovale, and mandibular condyle with each approach compared with endoscopic Denker approach

	FR	FO	MC
MM	0.001 ^a	0.002 ^a	0.03 ^a
EMM	0.001 ^a	0.002 ^a	0.009 ^a
Transseptal	0.008 ^a	0.001 ^a	0.006 ^a
SAM	0.44	0.39	0.26

Abbreviations: EMM, extended medial maxillectomy (anteriorly); FO, foramen ovale; FR, foramen rotundum; MC, mandibular condyle; MM, medial maxillectomy; SAM, sublabial anterior maxillotomy.

^aThe *p* value (*p* < 0.05 is statistically significant).

Discussion

Endoscopic endonasal surgery has revolutionized skull base surgery. However, surgical approaches to the infratemporal fossa remain technically demanding and require significant expertise. Adequate visualization and ease of instrument maneuverability are fundamental for a successful surgery in this area. Traditional open approaches meet these requirements by mobilizing or resecting large volumes of tissue. Contrary to the perceived notion that open approaches offer a larger working space, Fahmy et al, based on volumetric analysis, found strikingly similar results for endoscopic and open approaches.¹⁵ Therefore, the wide entry gate for instruments of open procedures does not necessarily translate into a wider exposure of the surgical target.

The endoscopic anatomy of this complex region has already been well described.^{11,16–21} This cadaveric model provides objective data for comparing approaches in terms of radial access and surgical freedom, which are important

determinants for the selection of a surgical approach in individual cases. However, one must consider that other critical factors such as age of the patient (i.e., status of craniofacial development), intrinsic and ethnic anatomical variations, pathology and histologic grade (benign or malignant, low or high grade), surgeon's training, patients preferences, and potential morbidity of the approach cannot be comprehensively considered in a cadaveric model. Therefore, the advantages described in our results should not be construed as a recommendation for any specific approach. The purpose is to enhance the understanding of caveats and advantages inherent to the approaches under controlled conditions.

The MM was described as an open procedure by Sessions and Larson in 1977.²² Kamel, in 1995, described the use of an endoscopic MM for the treatment of inverted papillomas.²³ Theodosopoulos et al reported that the lateral pterygoid plate represented the lateral limit of the exposure afforded by an MM.⁶ However, in this study, an endoscopic MM provided seemingly adequate exposure of not only the pterygopalatine fossa but also the most medial aspect of the infratemporal fossa (→Fig. 6). Anterolaterally the posterior wall of the maxillary sinus was exposed, and the temporalis muscle became the lateral limit. Although most of these structures could be visualized, as we progressed posterolaterally the instrumentation became exceedingly difficult. The nasolacrimal duct limits the anterior and lateral exposure afforded by this approach. Various MM techniques that spare the inferior turbinate have been described and may be advantageous in particular clinical scenarios. However, for the purpose of this study, the inferior turbinate was resected in all the specimens.^{24,25}

An EMM involves the removal of bone extending from the posterior aspect of the nasolacrimal duct to the pyriform aperture. Additional removal of this relatively small amount of bone displaces the fulcrum of the endoscope to an area anterior to the nasolacrimal duct, therefore resulting in a significant increase in lateral access, area of exposure, and surgical freedom. Our cadaveric study demonstrated that the area of exposure and surgical freedom at the foramen rotundum and the foramen ovale were similar for the EMM and the transseptal approach. The area of exposure and surgical freedom in these two approaches were superior than those afforded by the MM approach.

Accessibility to the lateral infratemporal fossa can be improved by maneuvering the instruments from the contralateral side. Others have suggested techniques that follow a similar concept, such as the transseptal approach by Harvey et al, nonopposing septal incision by Robinson et al, and septal dislocation by Ramakrishnan et al.^{7,26,27} Harvey and colleagues reported increased angulation for straight instruments and improved accessibility to infratemporal fossa lesions by an anterior transseptal approach; however, they also warned about the potential for septal perforation and loss of nasal support. The use of angled lens endoscopes obviously improves the area of visualization. However, this will also require the use of instruments of similar angulation, thus increasing the difficulty for instrumentation.

Fig. 6 Endonasal endoscopic cadaveric dissection of the infratemporal fossa using a 0-degree endoscope: (A) Posterior wall of the maxillary sinus as seen after the removal of the bone with intact periosteum. The sphenopalatine artery is identified and the bone is removed from the posterior wall of the maxilla starting at the sphenopalatine foramen and extending laterally. (B) Terminal branches of the internal maxillary artery are visualized after removing the posterior wall of the maxillary sinus and the periosteum: 1, infraorbital artery; 2, anterior superior alveolar artery; 3, greater palatine artery; 4, sphenopalatine artery. (C) Mandibular nerve is seen exiting the foramen ovale: 1, foramen ovale; 2, mandibular nerve; 3, lateral pterygoid muscle. (D) Mandibular nerve branches seen coming out of foramen ovale: 1, eustachian tube; 2, lingual nerve; 3, inferior alveolar nerve; 4, buccal nerve. (E) Middle meningeal artery, which is a branch of the maxillary artery, is seen entering the foramen spinosum. The maxillary artery winds around the neck of the middle meningeal artery. 1, middle meningeal artery; 2, auriculotemporal nerve; 3, foramen spinosum; 4, mandible; 5, internal maxillary artery. (F) Dissection of the carotid sheath. 1, spine of sphenoid; 2, middle meningeal artery; 3, internal carotid artery; 4, internal jugular vein; 5, cranial nerve IX; 6, nerve X-XII complex; 7, ascending pharyngeal artery; 8, deep lobe of the parotid.

We performed a generous posterior bony septectomy in all the specimens. It is our practice to use image guidance to ascertain sufficient septal cartilage is left to support the tip of the nose and also that the remaining septum is well supported on the maxillary crest. This ensures adequate support to the nasal pyramid and obviates the possibility of saddling of the nasal dorsum while allowing maximum removal of the posterior septum (► Fig. 7).

The thick bone of the pyriform aperture was the limiting factor for accessing the most lateral part of the maxillary sinus and infratemporal fossa. An endoscopic Denker approach involved drilling of this thick bone. The original description by Alfred Denker in 1906 used a sublabial approach.²⁸ However, Canfield and Sturmann subsequently described the same technique via an endonasal approach.^{29,30} Although this approach has been used successfully for the treatment of inverted papillomas involving the posterolateral, anterior, and inferior walls (type 3 approach), the approach has not been extensively used for other lesions.^{31–35}

Removal of the thick bone from the anteromedial part of the maxillary sinus in the endoscopic Denker approach significantly decreased the surgical difficulty, as demonstrated by the increase in the area of exposure and surgical

Fig. 7 Sagittal view of navigation device using preoperative computed tomography. The probe indicates a point of septal transfixion that preserves enough septum to buttress the nasal pyramid and that is supported by the premaxillary bone.

freedom. Prosser et al performed a radio-anatomic study comparing the potential exposure offered by MM, contralateral transseptal approach, and Denker approach. Based on an analysis of deidentified CT scans, they found that using a MM, the most lateral point of the posterior maxillary wall could not be reached adequately.¹⁰ This is in accordance with our findings. With a 1-cm Denker approach, the entire postero-lateral wall could be accessed in 54% of cases. Ivan El Sayed and colleagues described the endoscopic anterior maxillotomy approach, which essentially involved drilling the pyriform aperture.³⁶ They found that a 1-cm increase in the pyriform diameter resulted in an 18% increase in angulation over that achieved by the transseptal approach. Similarly, our study showed an increase of 11% in the lateral reach over that obtained by a transseptal approach. Furthermore, Prosser et al found that to obtain a lateral access equivalent to that offered by a 1-cm Denker approach, a septotomy had to be extended anteriorly to an average of 1.56 cm posterior to the columella. This extension precludes the preservation of a 1.5-cm columellar strut in 44% of patients, therefore increasing the risk of dorsal saddling.¹⁰

Despite the excellent exposure obtained with a Denker approach, it has not gained wide acceptance. Concerns regarding the disruption of the medial maxillary buttress with the possible loss of lateral alar support may contribute to its lack of popularity.¹⁰ Another consideration, especially important in the pediatric population, would be the disruption of growth centers with subsequent midfacial deformity. El Sayed et al reported nasal ala retraction of ~2 mm in 50% of their patients in accordance with the amount of anterior maxillary wall resected.³⁶ We concur that avoiding a Denker approach in the pediatric population seems prudent. However, the extent of removal of the anterior maxillary wall can be tailored according to individual needs, thus minimizing the potential for complications. Moreover, a Denker approach obviates the need for an extended septectomy or a separate sublabial incision.

Damage to the anterior superior alveolar nerve and its associated neurologic deficit, that is, localized anesthesia of the nasal ala and upper incisor, has also been described.³⁶ However, these complications are not limited to the Denker approach; they are also seen in the Caldwell-Luc and anterior maxillotomy approaches.^{10,37}

The Caldwell-Luc and anterior maxillotomy approaches have been extensively studied and serve as a standard for comparison of approaches to the infratemporal fossa. The anterior maxillotomy approach can be used independently or as a second port of entry while addressing lesions in the lateral skull base allowing two surgeons to work in tandem. Theodosopoulos et al reported that, when using a MM alone, the most lateral boundary corresponded to the lateral pterygoid plate. Addition of a Caldwell-Luc enabled these authors to expose the mandibular nerve, the middle meningeal artery, and 1.5 to 2 cm of the upper cervical carotid artery.⁶ Wilson et al⁸ compared the endonasal transmaxillary and the sublabial approach and provided data on the surgical freedom and angle of attack of the two approaches. According to their data, the mean surgical freedom was significantly higher for the Caldwell-Luc approach compared with the endonasal

transmaxillary transpterygoid approach. Elhadi et al compared the Caldwell-Luc with the ipsilateral endonasal and the transseptal approaches. They found that although the area of exposure was similar for all three, the maximum surgical freedom was obtained with the sublabial approach.¹³

Devaiah et al¹² described a cadaveric study comparing the EMM with the endoscopic-assisted sublabial transmaxillary approach to the infratemporal fossa, analyzing access and visualization. They found that although both approaches provided adequate access, the visualization and maneuverability were superior with the sublabial approach.¹²

Although abundant literature supports the superior surgical freedom with the Caldwell-Luc or anterior maxillotomy approach, there is equally no dearth of literature addressing complications associated with it. Neurologic complications like dental anesthesia, facial numbness, and pain have been extensively reported, with damage to the anterosuperior alveolar nerve the most likely explanation.^{37,38}

Little et al⁹ described an algorithm for surgical approach selection based on a line drawn from the anterior nasal septum through the nasolacrimal duct. These authors suggested approaching lesions medial to this line using an endonasal middle meatal corridor. They advocated a sublabial transmaxillary approach for lesions with an epicenter lateral to the line. The authors agreed that for laterally located lesions the exposure obtained by an MM may not be adequate and may need to be supplemented by additional maneuvers.

Based on the present data, we believe that an approach to the infratemporal fossa needs to be tailored to the specific lesion and the patient's anatomy. Location of the lesion and the direction of progression are important determinants. Lesions in the medial infratemporal fossa can be accessed by any of the approaches previously described; however, there are significant differences in surgical freedom among the approaches when reaching the lateral infratemporal fossa. Moreover, the surgical exposure can be sequentially and progressively increased to the desired point, thus minimizing unwarranted damage to the surrounding normal tissue. A combination of approaches can be utilized (dual port of entry) capitalizing on the specific advantage of the approach while minimizing the complications.

Conclusion

The endoscopic Denker approach seems to offer a similar radial access and area of exposure to that offered by a sublabial anterior maxillotomy approach. Moreover, the endoscopic Denker approach afforded superior surgical freedom at all the targets points. However, the morbidity associated with each of these approaches cannot be assessed using a cadaveric model. We advocate a graduated approach to the lesions in the lateral skull base.

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