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Evaluating Endoscopic Ipsilateral Endonasal Corridor Approaches to the Anterolateral Wall of the Maxillary Sinus: A Computerized Tomography Study

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Abstract

Introduction The endoscopic access to lesions in the anterolateral wall of the maxillary sinus is a challenging issue; therefore, the evaluation of access should be performed.
Objective To assess the accessibility of three endoscopic ipsilateral endonasal corridors.
Methods Three corridors were created in each of the 30 maxillary sinuses from 19 head cadavers. Accessing the anterolateral wall of the maxillary sinus was documented with a straight stereotactic navigator probe at the level of the nasal floor and of the axilla of the inferior turbinate.
Results At level of the nasal floor, the prelacrimal approach, the modified endoscopic Denker approach, and the endoscopic Denker approach allowed mean radial access to the anterolateral maxillary sinus wall of 42.6 ± 7.3 (95% confidence interval [CI]: 39.9–45.3), 56.0 ± 6.1 (95%CI: 53.7–58.3), and 60.1 ± 6.2 (95%CI: 57.8–62.4), respectively. Furthermore, these approaches provided more lateral access to the maxillary sinus at the level of the axilla of the inferior turbinate, with mean radial access of 45.8 ± 6.9 (95%CI: 43.3–48.4) for the prelacrimal approach, 59.8 ± 4.7 (95% CI:58.1–-61.6) for the modified endoscopic Denker approach, and 63.6 ± 5.5 (95%CI: 61.6–65.7) for the endoscopic Denker approach. The mean radial access in each corridor, either at the level of the nasal floor or the axilla of the inferior turbinate, showed a statistically significant difference in all comparison approaches ($p < 0.05$).
Conclusions The prelacrimal approach provided a narrow radial access, which allows access to anteromedial lesions of the maxillary sinus, whereas the modified endoscopic Denker and the endoscopic Denker approaches provided more lateral radial access and improved operational feasibility on far anterolateral maxillary sinus lesions.

Keywords
- endoscopic sinus surgery
- maxillary sinus
- radial access

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Introduction

Nowadays, endoscopy is widely used in sinus surgery. Almost all pathologies, especially those in the maxillary sinus, can be accessed and removed via either the standard endoscopic middle meatal antrostomy or the endoscopic medial maxillectomy. However, lesions occupying the anterior wall of the maxillary sinus represent a challenge as they need an extended surgical corridor, rather than the one provided by endoscopic medial maxillectomy.

The endoscopic surgical corridors proposed to manage anterior pathological lesions in the maxillary sinus include the prelacrimal approach (PLA) and the endoscopic Denker approach (EDA). The PLA, first described by Bing et al.,[1] requires removal of the anterior bony portion of the medial wall of the maxillary sinus (part of the frontal process of maxilla) as it forms the medial part of the prelacrimal recess. Kashlan and Craige[2] further defined the boundaries of bony resection in the PLA to include removal of bone up to the pyriform aperture anteriorly, the nasolacrimal duct posteriorly, the floor of the nose inferiorly, and the orbital floor superiorly. Regarding the EDA, it was described by Upadhyay et al.[3] as the removal of the anteromedial wall of the maxillary sinus without preserving the nasolacrimal duct and inferior nasal turbinate. This approach requires removal of the pyriform aperture and the anterior wall of the maxillary sinus medially at the level of the infraorbital nerve. Recently, there have been many modified techniques for these approaches, including the modified PLA, which involves removal of the medial part of the prelacrimal recess and the pyriform aperture, but not to the extent of the infraorbital nerve.[4] The present study was designed to evaluate the accessibility of three endoscopic surgical corridor procedures: the PLA, the modified endoscopic Denker approach (mEDA), and the EDA, in order to improve the planning of approaches for maxillary sinus surgery.

Material and Methods

Nineteen whole adult heads of fresh-frozen cadavers were enrolled. They were examined by nasal endoscopy and computerized tomography (CT) scan of the paranasal sinuses to assess the intranasal structure. Thirty maxillary sinuses met the eligibility criteria. The inclusion criteria were cadavers $>$ 18 years old; no presence of sinonasal tumor; no fracture or previous surgery of the maxillary sinus that could identify sinonasal structures of the lateral nasal wall (including inferior turbinate) and all walls of the maxillary sinuses; and good quality of imaging. Therefore, 8 maxillary sinuses (6 left and 2 right) were excluded due to previous surgery. The CT scanning was conducted with a Somaton plus4 CT scanner (Siemens Medical System, Erlangan, Germany) in axial, coronal, and sagittal views, following the protocol that the axial cut was parallel to the hard palate with a 4-mm slice thickness; the coronal cut was perpendicular to the hard palate with a 1.25-mm slice thickness, and the sagittal cut was parallel to the nasal septum with a 1.25-mm thickness. The data of the 19 heads were imported into the Medtronic StealthStation S7 navigator system (Medtronic plc, Minneapolis, MN, USA) for facilitating an evaluation of the radial access in each approach. Thirty eligible CT scans of maxillary sinuses were selected and analyzed from the 19 CT scan data of cadaver heads. All 30 maxillary sinuses were dissected in the same way, with the 3-stage surgical procedures including the PLA, the mEDA, and the EDA, respectively.

First of all, the cheek flap was elevated until the infraorbital foramen, to facilitate taking photographs for easier understanding and for comparison of the resection of the pyriform. In clinical practice, the cheek flap was not elevated. We made the vertical incision just anterior to the head of the inferior turbinate and the retraction of the subcutaneous tissue in the subperiosteal plane laterally. The first stage was the PLA, which removed the anterior bony portion of the medial wall of the maxillary sinus (part of the frontal process of maxilla) as it forms the medial part of the prelacrimal recess. The bony removal extended from the pyriform aperture anteriorly to the nasolacrimal duct posteriorly, and from the floor of the nasal cavity inferiorly to the orbital floor superiorly (►**Fig. 1A**). In the second stage, the mEDA removed the pyriform aperture and anterior wall of the maxillary sinus to midway between the pyriform aperture and the infraorbital foramen (►**Fig. 1B**). In the last stage, the EDA involved extended removal of the anterior wall of the maxillary sinus until the level of the infraorbital foramen (►**Fig. 1C**). The endoscopic view in each approach was observed with a zero-degree endoscope (►**Fig. 1D-F**).

The maximal endoscopic access to the lateral wall of the maxillary sinus of each endoscopic surgical approach (►**Fig. 2A-C**) was evaluated with a straight stereotactic probe and documented with a screenshot of the navigator system (►**Fig. 2D-E**). The endoscopic radial access was measured with the angle between the alignment of the probe tip that placed the most lateral spot and the alignment of the nasal septum at the level of the axilla of the inferior turbinate and the floor of the nose.

The access of the straight stereotactic probe to the bottom (►**Fig. 3A**) and the roof (►**Fig. 3B**) of the maxillary sinus was observed in each endoscopic approach (►**Fig. 3D-F**). Furthermore, the mean distance between the infraorbital foramen and the pyriform aperture was analyzed with the mark points on a screenshot of the navigator system at the level of the axilla of the inferior turbinate (►**Fig. 3C**).

The descriptive data were presented as percentages and mean $\pm$ standard deviation (SD). The mean endoscopic radial access was compared among all the approaches by independent paired *t*-test. Statistical analyses were performed with the IBM SPSS Statistics for Windows version 24.0. (IBM Corp., Armonk, NY USA) software. The study was approved by the local Human Ethics Research Committee (HE621153).

Results

The mean age of the cadavers was 73.5 years (range 44.0–91.0 years). There were 63.0% of male cadavers and 37.0% of female cadavers. The mean dimension of the maxillary sinus observed was of 29.9 $\pm$ 4.0 mm (95%CI: 27.8–32.0 mm) in mediolateral

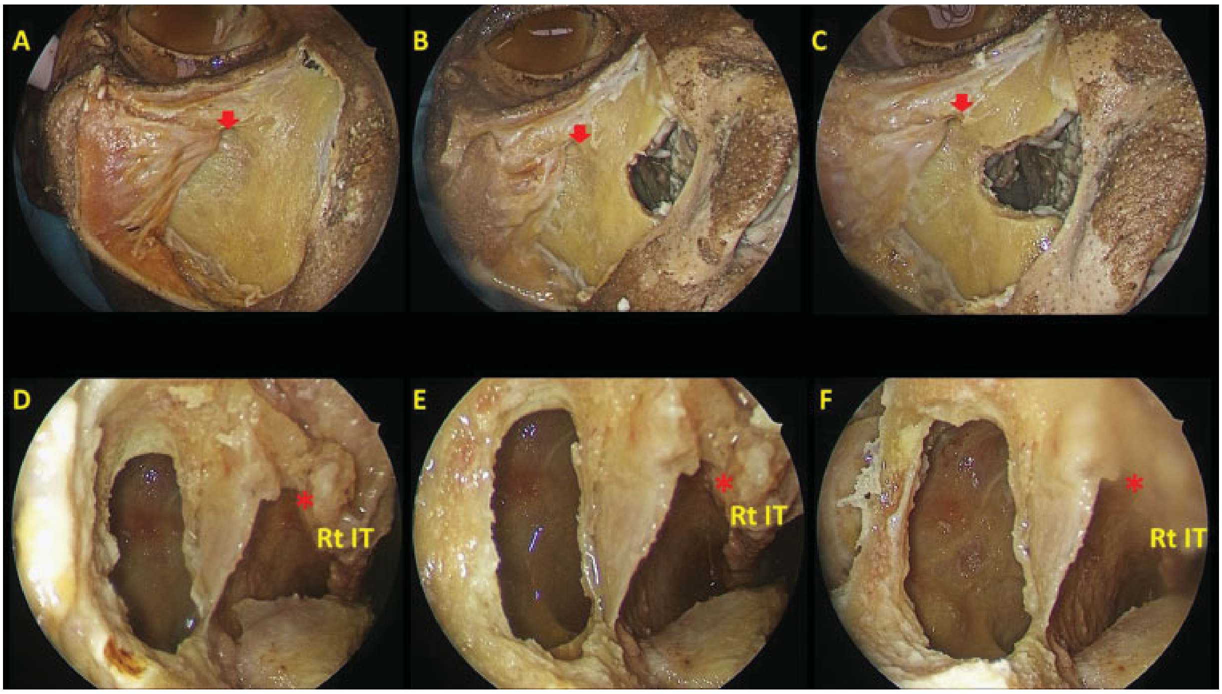

Fig. 1 The cheek flap was elevated until the infraorbital foramen to facilitate taking photographs for easier understanding and comparing the resection of the pyriform. In clinical practice, the cheek flap was not elevated. We made the vertical incision just anterior to the head of the inferior turbinate and the retraction of the subcutaneous tissue laterally. (**A**) The prelacrimal approach (PLA) only involved removal of the medial part of the prelacrimal recess with preservation of the pyriform aperture. (**B**) The modified endoscopic Denker approach (mEDA) removed the pyriform aperture and the anterior wall of the maxillary sinus to midway between the pyriform aperture and the infraorbital foramen (arrow). (**C**) The endoscopic Denker approach (EDA) involved extended removal of the anterior wall of the maxillary sinus until the level of the infraorbital foramen (arrow). The endoscopic view in each approach (**D**): endoscopic view of the PLA; (**E**): endoscopic view of the mEDA; (**F**): endoscopic view of the EDA to right maxillary sinus was observed with a zero-degree endoscope. Rt IT: right inferior turbinate; red asterisk: lacrimal duct.

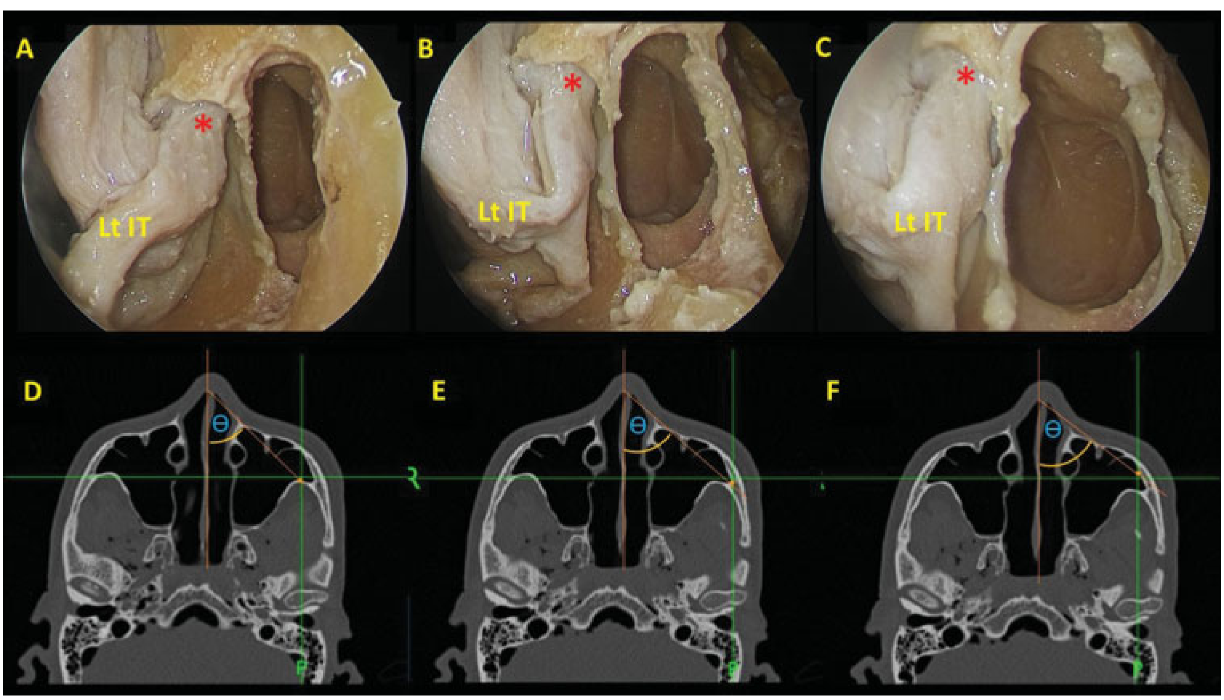

Fig. 2 The endoscopic approaches were created: **A:** prelacrimal approach (PLA); **B:** modified endoscopic Denker approach (mEDA); **C:** endoscopic Denker approach (EDA), and the angle (⊖) of endoscopic radial access on the screenshot of navigator system was measured. The angle at the level of the axilla of the inferior turbinate was demonstrated with the alignment of the probe tip, which was placed at the most anterolateral spot, and the alignment of the nasal septum (**D:** PLA; **E:** mEDA; **F:** EDA). Lt IT: left inferior turbinate; red asterisk: lacrimal duct.

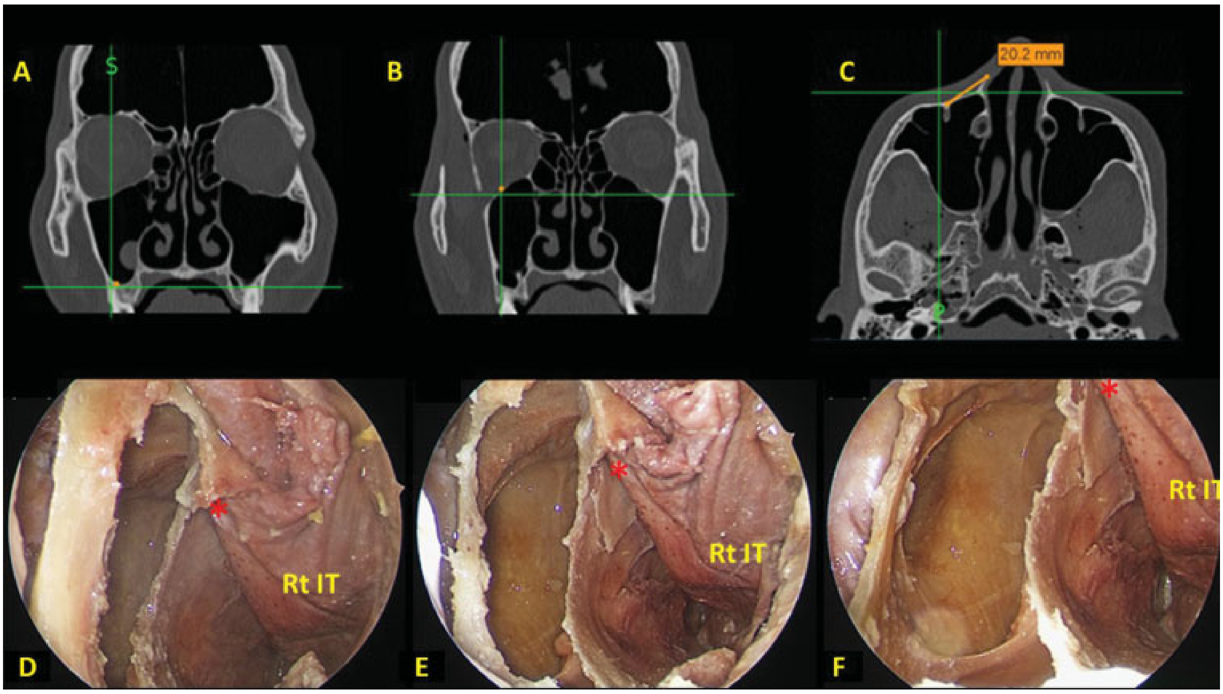

Fig. 3 Access of the straight stereotactic probe to the bottom (**A**) and the roof (**B**) of the maxillary sinus in each approach was observed (**D:** prelacrimal approach; **E:** Modified endoscopic Denker approach; **F:** endoscopic Denker approach. The distance between the infraorbital foramen and the pyriform aperture at the level of the axilla of the inferior turbinate (**C**) was measured. Rt IT: right inferior turbinate; red asterisk: lacrimal duct.

dimension; 37.2 ± 3.1 mm (95%CI: 35.6 –38.8 mm) in anteroposterior dimension; and mean height of 32.0 ± 4.4 mm (95%CI: 29.7–34.3 mm) on the right side, whereas on the left side, the observed mean was of 30.0 ± 5.1 mm (95%CI: 26.9–33.1 mm) in mediolateral dimension; 38.4 ± 3.0 mm (95%CI: 36.6–40.2 mm) in anteroposterior dimension; and mean height of 31.2 ± 4.0 mm (95%CI: 28.8–33.6 mm). The mean radial access at the level of the axilla of the inferior turbinate was wider than at the level of the nasal floor in all approaches. The EDA allowed the widest angle of mean radial access, at 63.6 ± 5.5 degrees (at the level of the axilla of the inferior turbinate) and 60.1 ± 6.2 degrees (at the level of the nasal floor), whereas the PLA provided the narrowest mean angle of radial access, at 45.8 ± 6.9 5 degrees (at the level of the axilla of the inferior turbinate) and 42.6 ± 7.3 degrees (at the level of the nasal floor). All of the mean differences for radial access in each pair were statistically significantly different ($p < 0.05$); however, the mean difference between the mEDA and the EDA presented a small difference in angle of 3.8 and 4.1 degrees, at the level of the axilla of the inferior turbinate and of the nasal floor, respectively (►**Table 1**).

In summary, all three endoscopic approaches facilitated the straight stereotactic probe to reach the roof and bottom of the maxillary sinus in all cadavers. The average distance between the infraorbital foramen and the pyriform aperture was 21.3 mm.

Table 1 Mean radial access and mean difference of endoscopic approach at the level of the axilla of the inferior turbinate and nasal floor inferior turbinate axilla

Endoscopic approaches	Mean radial access ± SD (degrees)			
	Level of the axilla of the inferior turbinate		Level of the nasal floor	
Prelacrimal approach (PLA)	45.8 ± 6.9 (95% CI: 43.3–48.4)		42.6 ± 7.3 (95% CI: 39.9–45.3)	
Modified endoscopic Denker approach (mEDA)	59.8 ± 4.7 (95% CI: 58.1–61.6)		56.0 ± 6.1 (95% CI: 53.7–58.3)	
Endoscopic Denker approach (EDA)	63.6 ± 5.5 (95% CI: 61.6–65.7)		60.1 ± 6.2 (95% CI: 57.8–62.4)	
Comparison of radial access between approaches	**Mean radial access difference**			
	Level of the axilla of the inferior turbinate	***P*-value**	**Level of the nasal floor**	***P*-value**
PLA vs mEDA	14.0 (95% CI: 11.0–17.1)	< 0.001	13.4 (95% CI: 10.0–16.9)	< 0.001
mEDA vs EDA	3.8 (95% CI: 1.1–6.4)	0.0061	4.1 (95% CI: 0.9–7.2)	0.0125
PLA vs EDA	17.8 (95% CI: 14.6–21.0)	< 0.001	17.5 (95% CI: 14.0–21.0)	< 0.001

Abbreviations: CI, confidence interval; SD, standard deviation.

Discussion

The present study evaluated the challenging issue of radial access for ipsilateral endoscopic endonasal approaches for managing anterolateral lesions of the maxillary sinus. There was a concern that the dimension of the maxillary sinus might affect the results of the study. The mean mediolateral dimension found in our study (29.9 mm on the right side and 30.0 mm on the left side) was slightly wider than those of a previous study[5] (26.2 mm on the right side and 26.9 mm on the left side). The wider mediolateral dimension may oppose the endoscopic endonasal approaches to far anterolateral lesions in the maxillary sinus. The mean anteroposterior dimension in our study (37.2 mm on the right side and 38.4 mm on the left side) was similar to that in the study by Lang and Papke,[5] who reported the mean of 38.4 mm on the right side and 39.1 mm on the left side; however, the height dimension in our study was shorter (mean of 32.0 mm on the right side and 31.2 mm on the left side) than that in the study by Lang and Papke[5] (mean of 40.0 mm on the right side and 40.8 mm on the left side). These findings suggest that all three approaches may allow access to reach the roof and bottom of the maxillary sinus in all cadavers.

Regarding the radial access of endoscopic approaches, we found that the EDA allowed the greatest radial access to the lateral wall of the maxillary sinus followed by the mEDA, and the PLA, respectively. A previous study, by Prosser et al.,[6] reviewed the axial computed tomography of the skull base and measured the angle between the line passing the anterior-maxillary wall 1 cm lateral to the pyriform aperture and the line passing through a standard maxillary antrostomy. This angle provided 33.5 degrees of exposure. El-Sayed et al.[7] developed the endoscopic anterior maxillectomy (EAM), which involved resection of approximately 1 cm of the nasal-frontal bar, similar to our mEDA. The EAM allowed ipsilateral radial access of 33.1 ± 5.9 degrees, which was less than the achieved with our technique, due to the smaller dimension of resection of the nasal-frontal bar and difference in the detailed measurement technique. Regarding the EDA, Upadhyay et al.[3] reported that it allowed radial access of 53.1 ± 4.7 degrees. It provided a smaller angle than that in our study, whether measured at the level of the axilla of the inferior turbinate (63.6 ± 5.5) or at the level of the nasal floor (60.1 ± 6.2). The cause for this discrepancy may be the different measurement techniques. Prosser et al.[6] and El-Sayed et al.[7] studied on the axial radiographic imaging that difficult to accurately mark the access point when compared with using the stereotactic probe of navigation system in our study. However, this is unclear when compared with the study of Upadhyay et al.,[3] who used the stereotactic probe, because the reference level for measuring the angle was not described. Regarding the PLA, the radial access was not mentioned; our study was the first inquiry to observe the lateral radial access of the PLA.

Our results provide a guide for endoscopic endonasal management of anterolateral pathological lesions in the maxillary sinus. The PLA provided the narrowest radial access that limited lateral access within the pyriform aperture; therefore, lesions attached to the anterior wall of the maxillary sinus, and more laterally, would be difficult dissections. Furthermore, the direction of the nasal endoscope and straight instruments may pass the more anterior lesion attached behind the pyriform aperture. Therefore, the mEDA was developed to extend the lateral resection of the pyriform aperture until midway between the edge of the pyriform aperture and the infraorbital foramen. The mean of the edge of the pyriform aperture and the infraorbital foramen observed was of 21.3 mm; therefore, the midway of the pyriform aperture and the infraorbital foramen was $\sim$ 10 mm, which allowed more radial lateral access and more exposure to more anterior lesions, which were hidden by the pyriform aperture. However, the mEDA is not necessary for lateral resection of the pyriform aperture until midway. Depending on the lesion, adjusted resection can be a minimally invasive surgery strategy. For far lateral lesions in the infraorbital foramen, the EDA may be considered to remove the remnant of the anterior wall of the maxillary sinus until the infraorbital foramen for additional lesion exposure and wider space for surgical freedom. Upadhyay et al.[3] showed that the EDA provided a superior area of exposure ($8.46 \pm 1.56\,cm^2$) and superior surgical freedom over other techniques, including endoscopic medial maxillectomy, anteriorly extended medial maxillectomy, transseptal approach, and endoscopic-assisted sublabial anterior maxillotomy. Furthermore, they mentioned that a Denker approach allowed a great extent of lateral access. Similarly, our study compared the EDA with the PLA and the mEDA, gaining significantly increasing radial access ($p < 0.05$). However, the EDA requires the resection of the pyriform aperture and anterior wall of the maxillary sinus, which disrupts the medial maxillary buttress, thus resulting in loss of lateral alar support[6] and disruption of the midfacial growth center in pediatric patients.[3] To avoid these complications, other endoscopic endonasal techniques have been developed. The mEDA is one of the alternative endoscopic endonasal approaches that uses a small resection of the pyriform aperture and anterior wall of the maxillary sinus of $\sim$ 10 mm, or a modified resection (< 10 mm) can be used depending on the extension of the lesion. El-Sayed et al.[7] reported that 50% of their patients experienced a little bit of nasal alar retraction due to loss of lateral support caused by resection of nearly 10 mm of the pyriform aperture. Therefore, the mEDA may be an alternative technique for decreasing subsequent facial deformity. Decreasing bony resection of the pyriform aperture and anterior wall of the maxillary sinus does not decrease radial access too much. Our study found that, compared with the mEDA, the EDA allowed a small increasing radial access of 3.8 degrees at the level of the axilla of the inferior turbinate and of 4.1 degrees at the level of the nasal floor. However, this small increase in radial access may not provide great benefits, and it is counteracted by the obvious nasal alar retraction. Although far anterolateral maxillary lesions may be difficult to dissect via the mEDA, this problem may be eliminated by using an angle endoscope and angle instruments. Besides, the other temporary complications, such as loss of sensation in the peri-alar skin and dental anesthesia, will improve around 12 months after resection of the 10 mm of the pyriform aperture.[7] The epiphora complication is one of the concerning issues of the EDA/mEDA, due to resection of the nasolacrimal duct; however, this complication can be prevented with the oblique sharp cut of the duct. Lee et al.[8] reported that no patients had experience with permanent postoperative epiphora in their series with the mEDA.

Other endoscopic endonasal techniques have been developed for maneuvering surgical instruments from the contralateral nasal nare through the nasal septum for managing anterolateral maxillary lesions, including the transseptal approach,[9] septal dislocation,[10] and nonopposing septal incision[11]. These approaches facilitate access to the anterolateral wall of the maxillary sinus; however, there is a high chance of potential complications, including septal perforation and loss of nasal support.

The limitation of our study is that the radial access was measured by only a straight stereotactic probe with a zero-degree endoscope; therefore, the benefits of angle instruments and angle endoscope are not demonstrated and not proved yet. Furthermore, our study compared the PLA with other endoscopic ipsilateral endonasal approaches (mEDA, and EDA) but did not include a comparison with the endoscopic contralateral endonasal approach via the nasal septum. Thus, further studies on this should be conducted.

Conclusion

The PLA allowed small radial access to manage anteromedial lesions of the maxillary sinus, whereas the mEDA and the EDA provided more lateral radial access with more feasibility for operating on far lateral maxillary sinus lesions. The mean difference in radial access between the mEDA and EDA is small; therefore, when planning nasal corridor strategies, surgeons should consider the possible complications in order to achieve excellent surgical outcomes.

Conflict of Interests
The authors have no conflict of interests to declare.

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