Morphometric Measurements of the Anterior Skull Base for Endoscopic Transoral and Transnasal Approaches

Bradley C. Lega, M.D.,¹ Daniel R. Kramer, B.A.,¹ Jason G. Newman, M.D.,² and John Y.K. Lee, M.D.¹

ABSTRACT

The objective of this study is to determine the bony limits of the transnasal and transoral approaches to the anterior skull base. The data we present are meant to assist surgeons in preoperative planning for lesions of the sella, clivus, foramen magnum, and odontoid. Using precise measurements undertaken on 41 high-resolution computed tomography scans from patients at the University of Pennsylvania without any history of sinus or sellar pathology, we sought to define the bony limits of transoral and transnasal approaches. Direct measurements and calculated angles were used to assess the dimensions of the anterior skull base. Using our measurements, a transnasal approach can reach an average of 22.5 mm below the plane of the hard palate to the body of C2, and a transoral route can reach 38 mm above the basion along the length of the clivus. Analysis of variance demonstrated no significant differences when subjects were grouped based on race or gender. The measurements outlined within this article help to define the relative dimensions necessary for adapted transoral and transnasal skull base surgeries.

KEYWORDS: Skull base, morphometry, transoral, transnasal, endoscopic surgery

The rise of endoscopic skull base surgery has seen minimally invasive, natural orifice techniques exploited to provide access to sensitive structures such as the brain, odontoid, intracranial vasculature, and cranial nerves.^{1–9} The superior visualization of the endoscope and the rapidly advancing use of robotic surgical procedures have led skull base surgeons to use minimally invasive techniques to treat increasingly complex pathology.^{10–12} As surgeons become more aggressive in their implementation of these techniques, the need will increase for a more precise geometric understanding of the bony limits of the oral and nasal cavities and associated endoscopic or robotic approaches. By analyzing high-

quality computed tomography scans with coronal and sagittal reconstructions to measure specific dimensions in the oral cavity and nasal cavity, we hope to provide a useful adjunct for surgical planning.

Our group at the University of Pennsylvania has applied transoral robotic techniques initially designed for lesions of the base of the tongue and larynx to the problem of accessing the anterior skull base.^{13–15} As a preclinical study, we conducted cadaveric robotic dissections targeting the sella, clivus, and odontoid.^{16–18} The tight confines of the oral and nasal cavity made these approaches challenging. Other experimental approaches have similarly demonstrated the possible application of

Departments of ¹Neurosurgery and ²Otorhinolaryngology–Head and Neck Surgery, University of Pennsylvania, Philadelphia, Pennsylvania.

Address for correspondence and reprint requests: Bradley C. Lega, M.D., Department of Neurosurgery, University of Pennsylvania, Silverstein 3, 3400 Spruce Street, Philadelphia, PA 19105 (e-mail: Bradley.Lega@uphs.upenn.edu).

Skull Base 2011;21:65–70. Copyright © 2011 by Thieme Medical

Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1 (212) 584-4662.

Received: March 6, 2010. Accepted after revision: July 6, 2010. Published online: September 14, 2010.

DOI: <http://dx.doi.org/10.1055/s-0030-1265825>.

ISSN 1531-5010.

the da Vinci surgical robot to parapharyngeal and infratemporal fossa operations.^{11–19} The da Vinci is not a monoaxial instrument; the robotic arms enter the field at a significant lateral angle. As such, the transoral and transnasal technique are sometimes useful in combination, and prior knowledge of hard palate–clivus–sella relationships is necessary to plan for the best pathway to pathology. Along with assisting surgical planning in this way, the measurements undertaken in this article will inform the rational design of new robotic surgical implements by providing designers with an estimate of the working spaces and distances that constrain movements in the anterior skull base.

For approaches through the oral cavity, the limits of the anatomic space are the hard palate superiorly and the lower teeth inferiorly. This opening depends on a measure of interincisal distance, which in turn depends on maximum mouth opening. This value has been previously reported with high variability. However, a meta-analysis by Zawawi et al showed that 40 mm is an average value for maximal opening.²⁰ Reaching the structures of the retropharynx requires a straightforward anterior-posterior insertion of instruments. The hard and soft palates make it difficult to reach superiorly, and the position of the foramen magnum relative to the hard palate significantly affects what pathology can be reached via a transnasal or transoral approach. We surmised that documenting an average value for the palate–foramen magnum relationship would prove useful to several applications beyond our immediate purposes.

The superior and lateral anatomic limits of the nasal cavity and sphenoid sinus that delimit the transnasal approach to the skull base have been discussed extensively in the sinus literature.^{21–23} We applied our methods selectively to define the inferior reach of the transnasal approach, specifically examining the length of the hard palate, the bony diameter of the nasal opening, and distances between the back of the hard palate and the clivus or foramen magnum. Where possible, we compared our measurements to existing data, although previous studies have focused primarily on subjects with abnormal skull base morphology resulting from basilar invagination or other pathology.^{24,25}

METHODS

A consecutive sample of 41 high-resolution computed tomography scans were reviewed and the relevant anatomic distances measured using standard DICOM software (DesAcc Inc., Chicago, IL). The scans were generated from consecutive neurosurgical patients undergoing imaging for neurovascular diagnoses, such as subarachnoid hemorrhage or intracranial carotid stenosis. The sagittal measurements were taken from a midsagittal view, which was determined as the point of

Figure 1 Measurements taken from a midsagittal, high-resolution computed tomography scan. Distance 1 (1.1) represents the length of the hard palate; 1.2 is the distance from the posterior extent of the hard palate to the first bony structure of the skull base, either the clivus or the bony process of C1; 1.3 shows the distance from the anterior-most point of the nasal bone to the plane of the hard palate; 1.4 provides the height of the hard palate above the inferior-most aspect of the odontoid. These measurements were used to calculate the angle of insertion from a transnasal approach. The nasopalatine line is indicated by 1.NPL and shows the inferior-most extent of a transnasal approach. The distance below the plane of the hard palate along the dens that a transnasal approach may reach is represented in 1.DENS.

maximal posterior extension of the hard palate. This point would create the maximum potential impediment to either a transnasal or transoral approach (see Figs. 1 and 2). Children and patients with a history of sinus, sellar, or other skull base pathology were excluded.

RESULTS

Transnasal Limitations

All measurements for transnasal and transoral insertion are listed in Table 1 and represented in Figs. 1 and 2. The patients were on average 50.4 years old (standard deviation 21.39), 59% male and 41% female, 39% white, 37% African-American, 7% Asian, and 17% unlisted. Results of a two-way analysis of variance regarding gender and race were not significant ($p = 0.23$), although the study was only powered to detect a 10% difference between groups given the size of the standard deviation of each measurement.

The length of the hard palate was the primary distance used for calculation of the inferior and superior reach of each approach (1.1 and 2.1 in Figs. 1 and 2), along with the distance from the hard palate to the first bony structure in the oropharynx (1.2, 2.2). The perpendicular distance from the nasal bone to the extension of the line of the hard palate is demonstrated in Fig. 1

Figure 2 Measurements taken from a midsagittal, high-resolution computed tomography scan. The first distance, 2.1, represents the length of the hard palate; 2.2 is the distance from the posterior extent of the hard palate to the first bony structure of the skull base, either the clivus or the bony process of C1; 2.3 indicates the distance from the plane of the hard palate to the inferior extent of the incisors; 2.4 is the maximum oral opening from Zawawi et al²⁰; 2.5 represents the length of the clivus from the basion to the midpoint of the sella. These distances were also used to calculate the angle of insertion for a transoral approach to skull base pathology. The oropalatine line is represented by 1.OPL and reveals the superior reach of a transoral approach. The distance that a transoral approach can reach along the clivus is represented by 2.CLIVUS.

(1.3). This represents the inferior-superior height of the opening to the nasal cavity and is 35.96 mm. In practice, nasal cartilage will alter this distance slightly. The direct distance from the tip of the nasal bone to the posterior-most portion of the hard palate has been previously described as the nasopalatine line (Fig. 1, 1.NPL).²⁴ The length of this line is on average 67.63 mm in our data, and the acute angle this line forms with the hard palate line is 32.1 degrees.

Using the principal of the nasopalatine line, de Almeida et al described a method to determine the inferior reach of a transnasal approach.²⁴ For this calculation, the nasopalatine line can be combined with the height of the anterior tip of the nasal bone above the hard palate (35.96 mm, Fig. 1, 1.3) and the distance from the posterior-most portion of the hard palate to the first bony structure of the skull or pharynx (1.2). These three measurements can be used to calculate the maximum inferior reach of the transnasal route using trigonometry. Following these methods, our data suggested that transnasal insertion permits an average of 22.46 mm of inferior reach (22.46 mm below the plane of the hard palate, represented by 1.DENS). How far a reach is possible depends on all of the aforementioned distances: a nasal bone that protrudes further, a large and immobile soft palate, or a hard palate that extends more posteriorly would reduce its magnitude. We found that the foramen magnum typically sits within 2 mm of the plane of the hard palate, placing it well within these constraints. We also measured the distance from the plane of the hard palate inferiorly to the midbody of C2, which we found is 19.81 mm on average (1.4). Given these two values, a transnasal insertion could, at its maximum, reach the body of C2 but not the C2-C3 disc space.

Transoral Limitations

We were interested in determining how much of the clivus can be reached via a transoral approach. Figure 2 shows the exact dimensions we measured: 2.1 and 2.2 are the length of the hard palate and distance from the hard palate to the clivus, analogous to the distances (1.1 and 2.1) in Fig. 1; 2.3 is the distance from the top of the hard palate to the bottom of the teeth, measured at the central incisors; 2.4 is the average height of maximal mouth opening, estimated from the literature to be 40 mm.²⁰ From these distances, the maximum angle of insertion can be calculated for an inferior-to-superior approach.

Table 1 The Means and Standard Deviations for All Values Measured

	Designation in Figs. 1 and 2	Average	SD
Length: hard palate	1.1, 2.1	48.30	4.07
Length: posterior-most tip of hard palate to first bony structure of the nasopharynx	1.2, 2.2	35.77	4.9
Height: anterior nasal bone to hard palate	1.3	35.96	3.5
Distance: anterior nasal bone to posterior hard palate	1.NPL until posterior hard palate	67.63	3.39
Height: hard palate to inferior dens	1.4	19.81	5.8
Distance: nasopalatine line limit below hard palate	1.DENS	22.47*	
Height: inferior tip of upper incisors to hard palate	2.3	27.71	4.14
Maximum oral opening ¹⁶	2.4	40	
Distance: basion to midpoint of sella	2.5	42.80	4.31
Distance: oropalatine line limit along clivus	2.CLIVUS	38.6*	

*Calculated.

Detailed explanations of the measurements are outlined in the text and shown in Figs. 1 and 2. Calculated values have no standard deviation (SD). The maximum oral opening is obtained from the literature.

This calculated value is 54.5 degrees. Also, using methods similar to those described by de Almeida et al, we can draw the “oropalatine line” (Fig. 2, 2.OPL) from the tip of 2.4 (lower incisors if the mouth is open) to the back of the hard palate and then posteriorly/superiorly to the skull base.²⁴ The point at which this line intersects the clivus provides an estimate of the theoretical maximum anatomic target that can be accessed through a transoral route. We measured the length of the clivus from the foramen magnum to the midpoint of the sella to be 41.4 mm on average (2.5). Along this length, the oropalatine line (2.OPL) intersects the clivus at a point 38.6 mm above the basion (Fig. 2, 2.CLIVUS). This distance is our estimate of the superior reach of a transoral route above the plane of the hard palate along the clivus.

Drilling the Hard Palate

Drilling the hard palate can theoretically improve both transoral and transnasal access. We calculated the effect of putative palate drilling on the respective approaches. For every millimeter drilled off of the posterior-most aspect of the hard palate during a transnasal operation, one can achieve an approximate increase in angle from the hard palate of 0.47 degrees. This translates into an exponentially increasing inferior reach from the transnasal approach, achieving a 0.63-mm increase in inferior reach for the first millimeter removed and 4.39 mm after 4 mm are removed. A commensurate increase in approach angle is achievable with palate drilling for the transoral approach.

DISCUSSION

Transnasal endoscopic surgery has become the workhorse of minimally invasive approaches to the anterior skull base. As neurosurgeons and their otorhinolaryngologist partners seek to move beyond sellar pathology and anterior skull base lesions, the relationship of the palate to the clivus, the foramen magnum, and the dens will become more important for determining the optimal approach to reach pathology. For inferior lesions or a foramen magnum sitting inferior to the plane of the hard palate, a transoral approach may be necessary. Our data indicate that, at most, a surgeon can expect to reach a point ~22 mm inferior to the plane of the hard palate via a transnasal route (Fig. 1, 1.DENS). This is a maximum; the soft tissues of the nose and especially the soft palate will change the maximum insertion angle and therefore affect the extent of the inferior reach. Similarly, de Almeida et al described a mean point of intersection of the nasopalatine line and the vertebral column at 8.9 ± 1.8 mm above the base of C2.²⁴ Their methods in this regard were slightly different (precluding a direct comparison), and their data set included many patients in whom the dens may sit higher relative to the hard

palate due to rheumatoid pathology. Despite these differences, our respective calculations point to similar conclusions about the limitations of a transnasal approach. We both found that the inferior body of C2 and the C2-C3 disc space are not within reach. Other values common to their work and ours are congruent (e.g., length of hard palate, nasopalatine angle). We found a maximum angle of attack of 32.1 degrees (angle of 2.OPL with the back of the hard palate). Baird et al showed a working angle of 28 degrees in three cadaveric specimens for this value; they also suggested that a transnasal approach would not allow full access to the inferior extent of C2.²⁵ Both previous studies included a limited number of subjects, with 17 patients studied by de Almeida et al and three cadavers dissected by Baird et al; however, the similarity of the values both groups reported to our own findings corroborate our methods and suggest that radiographic studies provide a useful complement to cadaveric investigations.^{24,25} Our results, taken from patients without significant skull base pathology, provide a more accurate measurement of the typical location of the foramen magnum relative to the hard palate; we found that it typically resides within 2 mm of the plane of the hard palate, making it accessible via either a transnasal or transoral approach.

Interest in transoral surgery has waned commensurate with improvement in techniques for transnasal endoscopic approaches. The utility of the transoral route for pathology above the foramen magnum is limited without angled endoscopic visualization. Microscopic techniques (constrained by line-of-sight optics) are especially limited by the hard palate. The point of maximum reach via a transoral route depends on factors such as the length of the upper incisors, the width of mouth opening, and the length of the hard palate. Based on the distances and maximum angle of insertion that we calculated, a superior reach of around 38.6 mm along the length of the clivus is possible (Fig. 2, 2.CLIVUS). This distance is also affected by the angle and position of the clivus relative to the hard palate. This 38-mm value incorporates only the lower two-thirds of the clivus based on our findings; angled scopes and instruments may be needed to reach the upper clivus or sella via the transoral approach without splitting the palate. The soft palate will decrease this reach, but in our experience, retraction techniques can minimize its effects. Complication rates from approaches such as the circumglossal or transmandibular approach reported in some series have indeed been daunting, ranging up to 31.6%; larger studies report rates of less than 20%.²⁶⁻³⁰ However, the infection rate itself for transoral surgery (separate from swallowing problems or other complications from extensive exposures) is generally less than 5%.²⁶⁻³⁰ The low incidence of methicillin-resistant *Staphylococcus aureus* colonization in the oral cavity as opposed to the nasal cavity³¹⁻³³ is an additional point to consider, especially if

instrumentation is ultimately contemplated. Our study is an important reminder of the potential utility of transoral approaches for reaching the clivus, especially in patients in whom the structure sits low relative to the hard palate. Although a more superior target would clearly benefit more from a transnasal approach, the use of a transoral approach is indicated when all or part of a target structure sits low enough for reach from a transoral approach and extends beyond the reach of a transnasal approach. This may be exaggerated in patients with high-riding hard palates. Additionally, for robotic surgery, the transoral route offers the unique advantage of a wider aperture for the insertion of instruments compared with the transnasal route. This permits the use of the articulated arms for complex movements such as suturing the pharyngeal mucosa or even the dura.^{11,14–18} Utilizing the advantages of a robotic transoral approach for pathology above the foramen magnum is feasible given our findings, especially with angled scopes and the wristed arms of the da Vinci.

We also report calculations for the additional reach afforded by drilling of the hard palate. Given the geometry, removal of 5 mm of bone improves the inferior reach by around 5 mm, although for each additional millimeter removed the payoff increases. The same is true for transoral approaches to the upper clivus and sella, as has been described previously by the South African group.³⁴

An additional means of improving visualization for transnasal surgery may include flexion or extension of the neck. de Almeida reported a single patient in whom they applied their methods to a flexion-extension X-ray, concluding that flexion improved the angle of attack.²⁴ Their assessment was confounded by the pathology of the patient they studied, who may have suffered abnormal motion-altering results. Our own assessment of dynamic X-rays has yielded equivocal results; a definitive study will require a dedicated analysis. Ultimately, it may differ from patient to patient.

The differences among race and gender were not found to be statistically significant in our study. As the size of the standard deviations of the measurements suggests, the variability across all subjects was far wider than the differences among groups. Surgical planning inevitably requires a review of a putative patient's imaging with specific attention to the distances we have measured. Our figures in turn can provide a useful rubric for distances that may affect a surgeon's choice of approaches and techniques and provide a quantitative outline for comparing alternatives when contemplating the treatment of anterior skull base lesions.

CONCLUSION

We have defined the theoretical maximum reach of transoral and transnasal surgical approaches to the

anterior skull base assuming the use of straight endoscopes and instruments. Using computed tomography images drawn from a relatively large data set of 41 patients, we provide a tool to assist surgeons in preoperative planning. A transnasal approach can reach pathology 22 mm below the plane of the hard palate, and a transoral approach can reach 38 mm along the clivus. The distances we define suggest quantitative means for assessing the relative utility of transnasal and transoral approaches for specific surgical candidates.

REFERENCES

- Gandhi CD, Christiano LD, Eloy JA, Prestigiacomo CJ, Post KD. The historical evolution of transsphenoidal surgery: facilitation by technological advances. *Neurosurg Focus* 2009; 27:E8
- Eloy P, Watelet JB, Hatert AS, de Wispelaere J, Bertrand B. Endonasal endoscopic resection of juvenile nasopharyngeal angiofibroma. *Rhinology* 2007;45:24–30
- Sciarretta V, Pasquini E, Farneti G, Frank G, Mazzatenta D, Calbucci F. Endoscopic sinus surgery for the treatment of vascular tumors. *Am J Rhinol* 2006;20:426–431
- Kassam AB, Mintz AH, Gardner PA, Horowitz MB, Carrau RL, Snyderman CH. The expanded endonasal approach for an endoscopic transnasal clipping and aneurysmorrhaphy of a large vertebral artery aneurysm: technical case report. *Neurosurgery* 2006;59(1 Suppl 1):ONSE 162–165; discussion ONSE162–165
- Cheng WY, Chao SC, Shen CC. Endoscopic microvascular decompression of the hemifacial spasm. *Surg Neurol* 2008; 70(Suppl 1):40–46
- Pletcher SD, Metson R. Endoscopic optic nerve decompression for nontraumatic optic neuropathy. *Arch Otolaryngol Head Neck Surg* 2007;133:780–783
- Kassam AB, Snyderman C, Gardner P, Carrau R, Spiro R. The expanded endonasal approach: a fully endoscopic transnasal approach and resection of the odontoid process: technical case report. *Neurosurgery* 2005;57(1 Suppl):E213; discussion E213
- Alfieri A, Jho HD, Tschabitscher M. Endoscopic endonasal approach to the ventral cranio-cervical junction: anatomical study. *Acta Neurochir (Wien)* 2002;144:219–225; discussion 225
- Gardner PA, Prevedello DM, Kassam AB, Snyderman CH, Carrau RL, Mintz AH. The evolution of the endonasal approach for craniopharyngiomas. *J Neurosurg* 2008;108: 1043–1047
- Kennedy DW. Technical innovations and the evolution of endoscopic sinus surgery. *Ann Otol Rhinol Laryngol Suppl* 2006;196:3–12
- Xia T, Baird C, Jallo G, et al. An integrated system for planning, navigation and robotic assistance for skull base surgery. *Int J Med Robot* 2008;4:321–330
- Pillai P, Baig MN, Karas CS, Ammirati M. Endoscopic image-guided transoral approach to the craniovertebral junction: an anatomic study comparing surgical exposure and surgical freedom obtained with the endoscope and the operating microscope. *Neurosurgery* 2009;64(5 Suppl 2):437–442; discussion 442–444

13. Weinstein GS, O'Malley BW Jr, Snyder W, Sherman E, Quon H. Transoral robotic surgery: radical tonsillectomy. *Arch Otolaryngol Head Neck Surg* 2007;133:1220-1226
14. O'Malley BW Jr, Weinstein GS. Robotic skull base surgery: preclinical investigations to human clinical application. *Arch Otolaryngol Head Neck Surg* 2007;133:1215-1219
15. O'Malley BW Jr, Weinstein GS. Robotic anterior and midline skull base surgery: preclinical investigations. *Int J Radiat Oncol Biol Phys* 2007;69(2 Suppl):S125-S128
16. Lee JYK, Lega B, Bhowmick D, et al. Da Vinci robot-assisted transoral odontoidectomy for basilar invagination. *ORL J Otorhinolaryngol Relat Spec* 2010;72(2):91-95
17. Lee JYK, O'Malley BW Jr, Newman JG, et al. Transoral robotic surgery of the skull base: a cadaver and feasibility study. *ORL J Otorhinolaryngol Relat Spec* 2010;72(4):181-187
18. Lee JYK, O'Malley BW Jr, Newman JG, et al. Transoral robotic surgery of craniocervical junction and atlantoaxial spine: a cadaveric study. *J Neurosurg Spine* 2010;12:13-18
19. Axlund TW, Behrend EN, Sorjonen DC, Simpson ST, Kempainen RJ. Canine hypophysectomy using a ventral paramedian approach. *Vet Surg* 2005;34:179-189
20. Zawawi KH, Al-Badawi EA, Lobo SL, Melis M, Mehta NR. An index for the measurement of normal maximum mouth opening. *J Can Dent Assoc* 2003;69:737-741
21. Zacharek MA, Han JK, Allen R, Weissman JL, Hwang PH. Sagittal and coronal dimensions of the ethmoid roof: a radioanatomic study. *Am J Rhinol* 2005;19:348-352
22. Lebowitz RA, Terk A, Jacobs JB, Holliday RA. Asymmetry of the ethmoid roof: analysis using coronal computed tomography. *Laryngoscope* 2001;111:2122-2124
23. Arian OK, Unal B, Kazkayasi M, Koc C. The analysis of anterior skull base from two different perspectives: coronal and reconstructed sagittal computed tomography. *Rhinology* 2005;43:115-120
24. de Almeida JR, Zanation AM, Snyderman CH, et al. Defining the nasopalatine line: the limit for endonasal surgery of the spine. *Laryngoscope* 2009;119:239-244
25. Baird CJ, Conway JE, Sciubba DM, Prevedello DM, Quiñones-Hinojosa A, Kassam AB. Radiographic and anatomic basis of endoscopic anterior craniocervical decompression: a comparison of endonasal, transoral, and trans-cervical approaches. *Neurosurgery* 2009;65(6 Suppl):158-163; discussion 63-64
26. Menezes AH. Surgical approaches: postoperative care and complications "transoral-transpalatopharyngeal approach to the craniocervical junction." *Childs Nerv Syst* 2008;24:1187-1193
27. Menezes AH, VanGilder JC. Transoral-transpharyngeal approach to the anterior craniocervical junction. Ten-year experience with 72 patients. *J Neurosurg* 1988;69:895-903
28. Perrini P, Benedetto N, Guidi E, Lorenzo ND. Transoral approach and its superior extensions to the craniovertebral junction malformations: surgical strategies and results. *Neurosurgery* 2009;March 11 [Epub ahead of Print]
29. Hadley MN, Spetzler RF, Sonntag VKH. The transoral approach to the superior cervical spine. A review of 53 cases of extradural cervicomedullary compression. *J Neurosurg* 1989;71:16-23
30. Jones DC, Hayter JP, Vaughan ED, Findlay GFG. Oropharyngeal morbidity following transoral approaches to the upper cervical spine. *Int J Oral Maxillofac Surg* 1998;27:295-298
31. Safdar N, Bradley EA. The risk of infection after nasal colonization with *Staphylococcus aureus*. *Am J Med* 2008;121:310-315
32. Davis KA, Stewart JJ, Crouch HK, Florez CE, Hospenthal DR. Methicillin-resistant *Staphylococcus aureus* (MRSA) nares colonization at hospital admission and its effect on subsequent MRSA infection. *Clin Infect Dis* 2004;39:776-782
33. Smith AJ, Robertson D, Tang MK, Jackson MS, MacKenzie D, Bagg J. *Staphylococcus aureus* in the oral cavity: a three-year retrospective analysis of clinical laboratory data. *Br Dent J* 2003;195:701-703; discussion 694
34. Rose-Innes AP, Oosthuizen JH. The transoral transpalatal approach to the pituitary fossa. *Minim Invasive Neurosurg* 1995;38:22-26