Int. J. Oral Maxillofac. Surg. 2023; 52: 633–639
https://doi.org/10.1016/j.ijom.2022.12.007, available online at https://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Reconstructive Surgery

# A comparative study of three-dimensional airway changes after fibula flap reconstruction for benign and malignant tumours in the anterior mandible

**W. Du[a,1], G. Liu[a,b,1], W. Zhang[a], N. Zhao[c], Y. Shi[b], X. Peng[a]**

[a]Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China; [b]Department of Stomatology, Liangxiang Hospital of Beijing Fangshan District, Beijing, China; [c]Institute of Quantitative Economics, School of Economics, Nankai University, Tianjin, China

*W. Du, G. Liu, W. Zhang, N. Zhao, Y. Shi, X. Peng: A comparative study of three-dimensional airway changes after fibula flap reconstruction for benign and malignant tumours in the anterior mandible. Int. J. Oral Maxillofac. Surg. 2023; 52: 633–639.* 

*Abstract.* Surgical treatment of tumours in the anterior mandible and surrounding tissues may result in defects which can be restored by a fibula free flap. The upper airway may change during this process. The purpose of this retrospective study was to evaluate upper airway changes after fibula free flap reconstruction. A total of 37 patients who underwent anterior mandibulectomy and fibula free flap reconstruction between 2012 and 2020 were recruited. Patients with benign and malignant tumours involving the anterior mandible were included. Spiral computed tomography was performed 1 week preoperatively, 1 week postoperatively, and at > 1 year (range 12–23 months) after surgery. Cross-sectional areas and volumes of the upper airway were measured. Data were analysed by two-way analysis of variance. The upper airway in the malignant tumour group showed an increasing trend, especially at the soft palate and tongue base levels ($P < 0.01$). In the benign tumour group, the upper airway showed no significant changes. The location of the minimum cross-sectional area moved downwards in both groups, and the area increased in the malignant tumour group during long-term follow-up. Upper airway obstruction is less likely to occur in the long term after surgical resection of anterior mandible malignancies and fibula free flap reconstruction.

Keywords: Reconstructive surgery; Spiral CT; Airway management; Mandibular neoplasms; Free tissue flaps.

Accepted for publication 19 December 2022
Available online 28 December 2022

[1] Wen Du and Guolin Liu are co-first authors.

*Table 1.* Clinical characteristics of the 37 study patients: group 1, malignant tumours; group 2, benign tumours.

| Location | Pathology | Cases | Neck dissection (postoperative radiotherapy) | BMI (kg/m²) | | |
|---|---|---|---|---|---|---|
| | | | | T0 | T2 | *P*-value |
| Group 1 (*n* = 26) | | | | | | |
| Floor of mouth<br>Gingiva<br>Mandible | Squamous cell carcinoma | 17 | Bilateral: 16 (2)<br>Unilateral: 1 (0) | 24.87 ± 1.4 | 20.79 ± 1.8 | 0.007 |
| | Adenoid cystic carcinoma | 4 | Bilateral: 1 (0)<br>Unilateral: 2 (1) | | | |
| | Osteosarcoma | 3 | 0 | | | |
| | Mucoepidermoid carcinoma | 1 | Bilateral: 1 | | | |
| | Malignant melanoma | 1 | Bilateral: 1 | | | |
| Group 2 (*n* = 11) | | | | | | |
| Mandible | Ameloblastoma | 5 | / | 24.17 ± 1.0 | 22.92 ± 1.3 | 0.14 |
| | Odontogenic keratocyst | 3 | / | | | |
| | Ossified fibroma | 2 | / | | | |
| | Giant cell tumour | 1 | / | | | |

BMI, body mass index; T0, 1 week preoperatively; T2, > 1 year after surgery.

Tumours occurring in the mandible and surrounding anatomical structures are commonly seen in clinical practice. Surgical resection is one of the most effective ways to treat this kind of disease.[1] However, the mandible occupies the lower third of the face and plays an important role in maintaining the facial contour and function. The treatment of these tumours may bring a series of functional and psychological problems to the patient, which is a difficult problem for clinicians.[2,3]

Breathing is a fundamental motor behaviour required for life. Maintaining airway patency is necessary after treatment.[4] The hyoid bone is attached to the mandible by the genioglossus, the geniohyoid muscle, the mylohyoid muscle, and the anterior digastric muscle. These anatomical structures play an important role in keeping the upper airway open.[5]

Defects of the mandible, especially the anterior part, could lead to the loss of genioglossus muscle attachment and glossoptosis, which may cause upper airway narrowing and even endanger the patient's life.[6] Most surgeons advocate for elective tracheostomy after mandibular resection,[7] although this can result in complications, such as bleeding, airway obstruction, pneumonia, and prolonged hospitalization.[8,9]

The fibula free flap is one of the most commonly used methods for mandibular reconstruction.[10] It can be used to restore the shape and function of the mandible in a single stage. The maintenance of the upper airway shape is an important objective of mandibular reconstruction. However, few studies have reported on upper airway volumes before and after fibula free flap reconstruction of the mandible,[11] especially when defects are in the anterior segment of the mandible. No research has focused on assessing long-term airway changes.

The purpose of this retrospective study was to analyse the difference in postoperative three-dimensional (3D) airway changes at different times between patients with benign and malignant tumours.

## Materials and methods

### Patients

The study was approved by the Ethics Committee of Peking University School and Hospital of Stomatology (PKUSS-IRB-202055073). Written informed consent was obtained from all patients. A total of 37 patients who underwent an anterior mandibulectomy and fibula free flap reconstruction at Peking University School and Hospital of Stomatology between June 2012 and June 2020 were recruited. The range of the resection included the area of the mandible corresponding to the bilateral canines. Patients with pathologies involving the upper airway, a medical history of allergic rhinitis, previous adenotonsillectomy, or subjectively perceived respiratory problems were excluded from the study.

The patients were divided into two groups based on the nature of the tumour. Patients with malignant tumours involving the anterior part of the mandible were allocated to group 1; these patients underwent partial removal of the tongue and the floor of the mouth. Patients with benign tumours of the mandible were allocated to group 2; these patients did not receive muscle excision. Most patients in group 1 received a unilateral or bilateral neck dissection depending on the nature and location of the tumour (Table 1). All surgeries were performed by the same medical team. The primary goal of the medical team was to restore the 3D shape of the mandible according to the patient's pre-treatment face contour, or appropriate facial proportions. The HCL classification of mandibular defects proposed by Jewer et al.[12] was used in this study. Details of the mandibular defects caused by the surgical resection are shown in Fig. 1.

Spiral computed tomography (CT) scans were taken 1 week preoperatively (T0), 1 week postoperatively (T1), and at > 1 year (range 12–23 months) after surgery (T2). All images were captured using the following CT parameters: field of view 20 cm, pitch 1.0, slice thickness 0.75 mm, voltage 120 V, and current 280 mA. Patients who were swallowing, had an abnormal head position, and those with inconformity of the craniocervical angle during CT imaging were excluded from the study. Patients were assessed for height and weight at T0 and T2. The change in body mass index (BMI) between these two time points was analysed in both groups.

### Three-dimensional reconstruction and measurements of the upper airway

The three-dimensional (3D) images obtained from the CT scans were saved in DICOM format (Digital Imaging and Communications in Medicine) and reconstructed with 3D Slicer (Slicer, version 4.11; www.slicer.org). Each image was reoriented using the Frankfort horizontal plane as the horizontal reference plane. The upper airway was divided into three parts by four reference planes (Fig. 2). Cross-

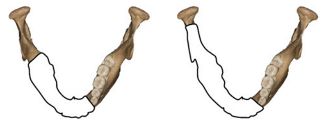
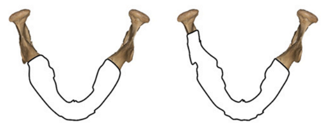
| Reconstruction Class | Mandibular Defect | Malignant Group | Benign Group |
|---|---|---|---|
| **C** |  | 1 | 1 |
| **LC** |  | 10 | 3 |
| **LCL** |  | 14 | 4 |
| **HC** |  | 0 | 2 |
| **HCL** |  | 1 | 1 |

*Fig. 1.* Summary of the mandibular defect for each reconstructive class.

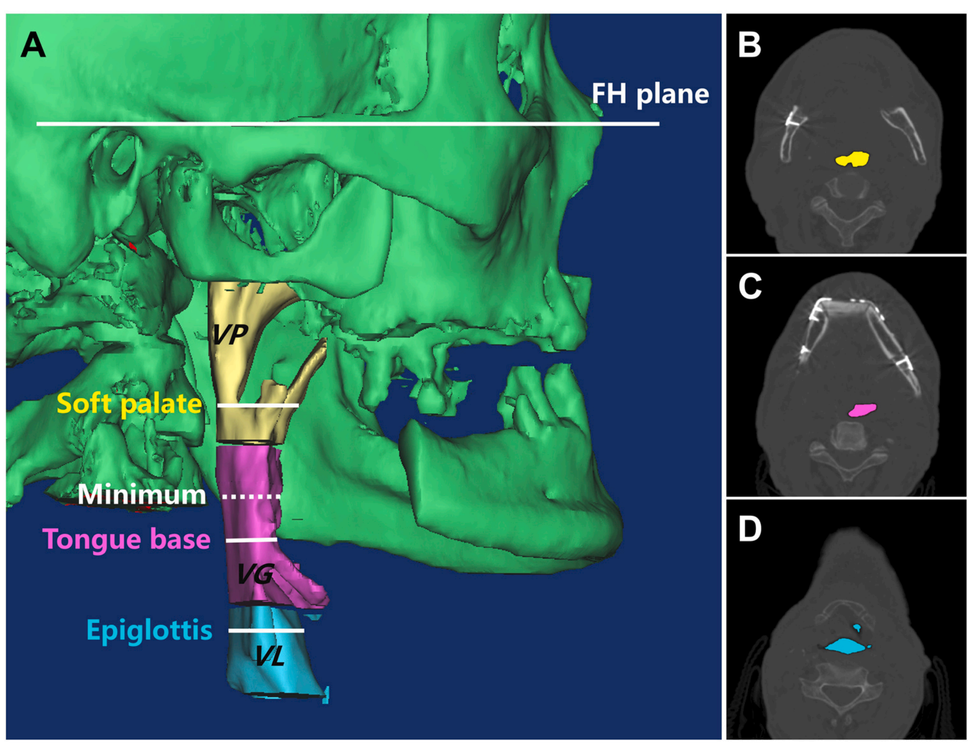



*Fig. 2.* Measurements of the airway volume and cross-sectional area examined in this study. (A) Section of the airway volumes and the reference planes for the cross-sectional area. VP is the volume of the palatopharyngeal part, VG is the volume of the glossopharyngeal part, and VL is the volume of the laryngeal part. The areas on the following reference planes were used: (B) soft palate plane (horizontal plane through the most inferior point of the soft palate), (C) posterior tongue base plane (horizontal plane through the most posterior point of the back of the tongue), (D) epiglottis plane (horizontal plane through the root of the epiglottis).

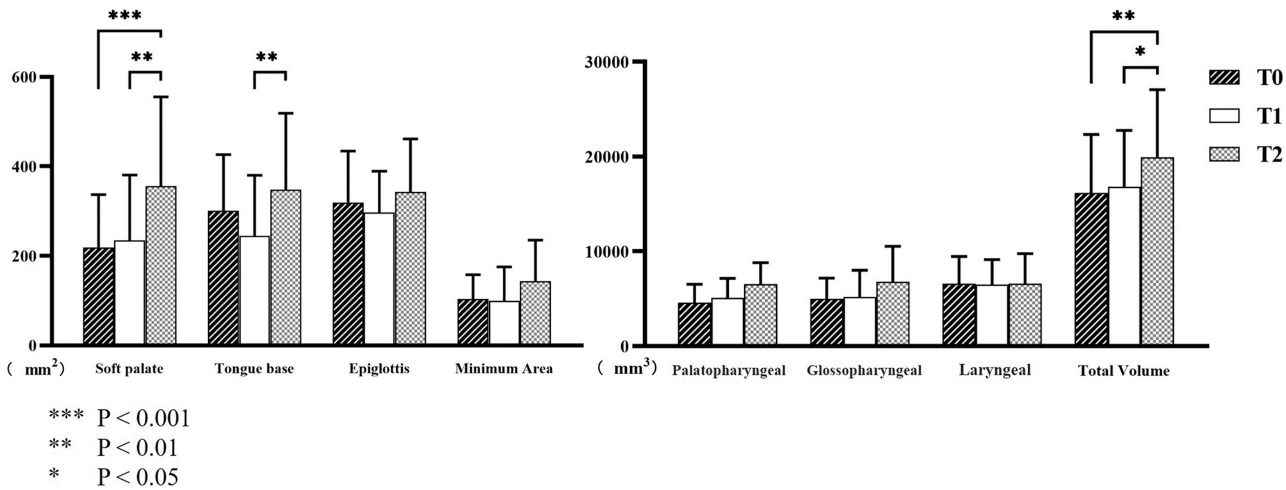



*Fig. 3.* The upper airway volumes and cross-sectional areas at T0 (preoperative), T1 (1 week postoperative), and T2 (> 1 year postoperative) in the malignant tumour group.

sectional areas were measured at different levels of the upper airway in horizontal planes (soft palate, tongue base, and epiglottis planes). The minimum airway cross-sectional area and its location were determined in all CT scans. The total volume of the upper airway and the volume of the palatopharyngeal, glossopharyngeal, and laryngeal portions were measured.

#### Statistical analysis

The change in BMI from preoperative to T2 after treatment was analysed by paired *t*-test. The upper airway volumes and cross-sectional areas were presented as the mean ± standard deviation. Two-way analysis of variance (ANOVA) was used to analyse the variances within the groups. The data were analysed using GraphPad Prism Software 8.0.1 (GraphPad Inc., San Diego, CA, USA). $P < 0.05$ was considered statistically significant.

## Results

#### Patient and clinical characteristics

A total of 37 patients were included in this study. Their clinical characteristics are summarized in Table 1. In the malignant tumour group, there were 21 male patients (mean age 60.08 ± 10.48 years) and five female patients (mean age 58.31 ± 15.76 years). In the benign tumour group, there were seven male patients (mean age 45.6 ± 17.93 years) and four female patients (mean age 40.89 ± 16.98 years).

The most common malignant tumour type was squamous cell carcinoma (17 patients); other types included adenoid cystic carcinoma, osteosarcoma, mucoepidermoid carcinoma, and malignant melanoma. The most common benign tumour type was ameloblastoma (five patients); others included odontogenic keratocyst, ossified fibroma, and giant cell tumour.

The exact extent of the neck dissection was decided mainly based on the tumour type and the preoperative imaging examination. All patients were intubated endonasally during surgery. A tracheotomy was performed at the end of the surgery.

The mean BMI of the patients in the two groups before and after surgery are shown in Table 1. The mean BMI in the malignant group had decreased at T2, and the change was statistically significant ($P = 0.007$). There was no statistically significant change in BMI in the benign tumour group.

#### Upper airway measurements

All patients underwent fibula free flap reconstruction after anterior mandibulectomy. The cross-sectional areas at the different levels and the volumes of the upper airway were calculated in 3D Slicer. The measurements obtained for the malignant tumour group and the benign tumour group are presented in Fig. 3 and Fig. 4, respectively.

In the malignant tumour group, the total volume of the airway at T2 was 19,932.5 ± 7138.12 $mm^3$, showing a significant increase when compared to the volume at T0 (16,164.1 ± 6162.57 $mm^3$; $P = 0.002$) and T1 (16,818 ± 5946.48 $mm^3$; $P = 0.014$). There was no significant change in the palatopharyngeal, glossopharyngeal, or laryngeal airway volumes between the different time points. However, the palatopharyngeal and glossopharyngeal airway volumes showed an increasing trend at T2. In the benign tumour group, there was no statistically significant difference in the total volume or the volumes of each segment between the different time points.

In the malignant tumour group, the airway cross-sectional area at the soft palate showed a significant increase at T2 when compared to T0 ($P < 0.001$) and T1 ($P = 0.002$), suggesting a widening of the upper part of the airway. The cross-sectional area of the airway at the tongue base increased significantly between T1 and T2 ($P = 0.009$). In the benign tumour group, there was no significant change in the airway cross-sectional area across the three time points at any level of the airway, except for a significant decrease in cross-sectional area at the tongue base level between T0 and T1 which was reversed at T2.

The minimum cross-sectional area in the malignant tumour group showed an increasing trend at T2; however, this change was not statistically significant ($P > 0.05$). In the benign tumour group, the minimum cross-sectional area showed a decreasing trend at T1, but then returned to the preoperative level at T2. The location of the minimum cross-sectional area showed a trend of moving downwards in both

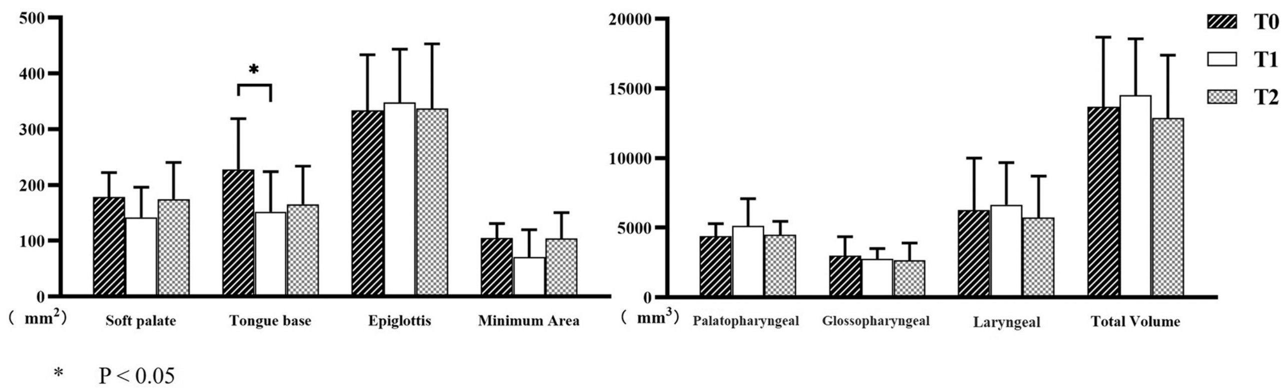



*Fig. 4.* The upper airway volumes and cross-sectional areas at T0 (preoperative), T1 (1 week postoperative), and T2 (> 1 year postoperative) in the benign tumour group.

groups. Details of the minimum cross-sectional area are shown in Fig. 5.

## Discussion

There is a lack of relevant studies on the possibility of postoperative airway stenosis and even the long-term occurrence of obstructive sleep apnoea for tumours in the anterior part of the mandible. In this retrospective study, CT volumes and areas were measured for patients treated with anterior mandibular tumour resection and fibula free flap reconstruction at the same time. The major finding of the current study was that significant upper airway widening occurred in patients undergoing anterior mandibular resection of malignant tumours and fibula free flap reconstruction, whereas no significant changes were noted in patients treated in the same way for benign tumours. The widening mainly involved the palatopharyngeal and glossopharyngeal levels.

Narrowing of the upper airway may lead to obstructive sleep apnoea syndrome.[13] The genioglossus is the most important muscle to keep the upper airway open, and surgery involving the floor of the mouth may significantly alter a patient's airway volume. For patients with upper airway narrowing, surgical intervention can reduce the stenosis of the airway.[4,14–16] The increase in muscle tension and myoelectric activity may be an important mechanism to prevent upper airway collapse.[17–20] In contrast, mandibular setback, loss of muscle attachment, and mandibular defects can reduce the volume of the upper airway or even induce obstructive sleep apnoea syndrome.[4]

The changes in the upper airway after surgery are the result of many factors. These factors can be classified into four key domains: tumour site, mandibulectomy, neck dissection, and reconstruction.[15] Key aspects of the reconstruction of anterior mandible defects are airway support and restoration of the facial appearance.[21] Only a few reports have summarized the risk factors for airway changes in such patients. Moubayed et al.[11] summarized factors for avoiding selective tracheotomy after fibula flap reconstruction of the mandible: the first was no soft tissue defects involving the

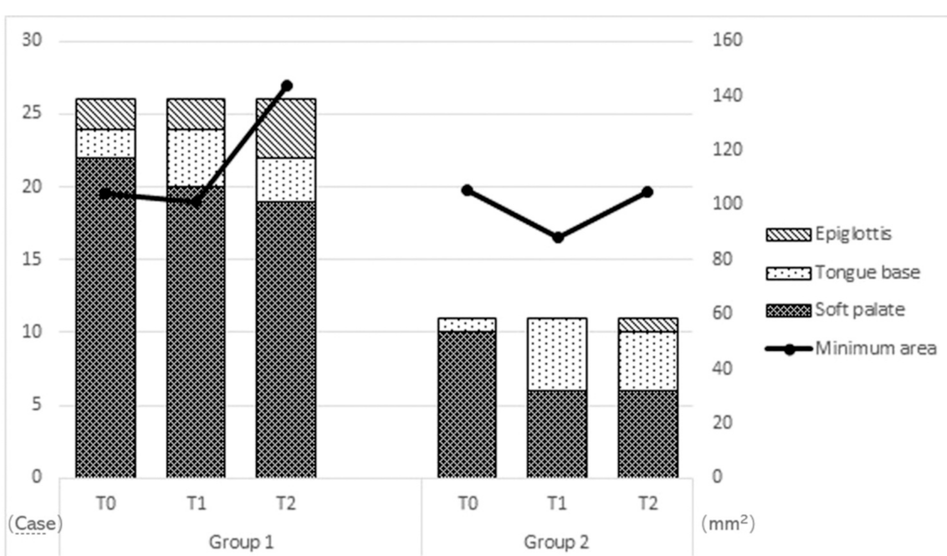



*Fig. 5.* Bar graph showing the distribution of the minimum cross-sectional area by location and illustrating the horizontal positional change of the minimum area over time. The line charts show the trend of the change in minimum cross-sectional area across the different time points.

tongue or pharynx, the second was mandibular defects only occurring unilaterally, and the third was no concurrent neck dissection, especially bilateral neck dissection. However, the current study found that for patients with benign tumours, even if the anterior mandible defect crossed the midline, there was no significant narrowing of the airway after fibula flap reconstruction. The upper airway volumes and cross-sectional areas in the benign tumour group did not show any significant changes between the three different time points, with the exception of the cross-sectional area at the tongue base level, which showed a significant decrease from T0 to T1. This trend was reversed during long-term postoperative follow-up. These results suggest that surgical resection and fibula free flap repair of tumours in this region will not have long-term effects on the upper airway. However, in this study, the first postoperative CT was taken 1 week after surgery, and the postoperative swelling and stress response period of the patient had already almost ended. The short-term postoperative airway condition still needs close attention from the surgeon.

For patients with malignant tumours occurring in and around the anterior part of the mandible, surgery will disrupt the original genioglossus muscle attachment and may cause glossoptosis. In addition, most malignant tumours require simultaneous unilateral or bilateral neck dissection, which may lead to swelling and narrowing of the upper airway due to blocked lymphatic reflux.[9,11] The overwhelming majority of scholars recommend active postoperative airway management in these patients.[22–24] However, studies on long-term airway changes in these patients are lacking.

In the malignant tumour group, the upper airway volumes did not show significant reductions at 1 week after surgery, but basically maintained the preoperative level. More interestingly, the total volume of the upper airway in this group increased significantly during the long-term postoperative follow-up. The volumes of the different segments of the upper airway also showed an increasing trend. Many factors may have led to this result. Firstly, malignant tumours occurring at this site require extensive surgical resection for radical treatment, which requires the removal of a large amount of the surrounding soft tissue. Reconstruction of the mandible with a fibula free flap is an effective way to repair the defect. However, the amount of muscle and skin island carried by the flap is limited, and sometimes cannot completely repair the soft tissue defect. Secondly, due to the change in the location, the muscle carried by the fibula free flap may atrophy due to the lack of neural electrical stimulation.[25] Moreover, long-term shrinkage of the skin island of the fibula flap may be observed due to the altered microenvironment. This process, together with scar contracture, may pull the tongue forward, resulting in further opening of the airway. The cross-sectional area at the palatopharyngeal and glossopharyngeal levels had increased significantly at T2, which was consistent with the change in the airway volume, indicating that airway enlargement occurred at a higher anatomical position. The increase in airway cross-sectional area at these levels may be due to the forward movement of the tongue. At the same time, the position of the hyoid bone did not change significantly.

The BMI is a neutral and reliable indicator when the health effects of obesity are needed for analysis.[26] In this study, the mean BMI of the patients in the malignant tumour group showed a significant decrease from T0 to T2. However, there was no significant difference in mean BMI between T0 and T2 in the benign tumour group. The range of the surgical resection of malignant tumours is larger. At the same time, postoperative radiotherapy, chemotherapy, anxiety, loss of chewing and swallowing function, and other factors may have caused this significant weight loss.[2,27] Changes in BMI may further affect the upper airway, and these changes are consistent with the trend in airway changes.

This study was a single-centre retrospective study, which may have limitations such as sample selection bias and an insufficient sample size. The airway changes were evaluated at three time points: 1 week before surgery, 1 week after surgery, and > 1 year after surgery, which can better reflect airway changes during this process. However, airway changes during the perioperative period could not be evaluated. In addition, only the static 3D structure of the upper airway was analysed to describe the changes in the patients, and these analyses could not fully reveal the changes in airway function. The dynamic changes and subjective functional changes in the airway need further study in the future. A prospective study that includes an analysis of airway fluid dynamics and polysomnography may lead to more conclusive results regarding the airway changes in these patients.

The results of this study suggest that upper airway obstruction is less likely to occur in the long term after surgical resection of anterior mandible malignancies and fibula free flap reconstruction.

## Funding

This study was supported by grants from the China Postdoctoral Science Foundation (2021M700278).

## Competing interests

None.

## Ethical approval

The study was approved by the Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-202055073).

## Patient consent

Not required.

## References

1. Balaji SM. Total reconstruction of mandible by transport distraction after complete resection for benign and malignant tumors. *Indian J Dent Res* 2016; **27**:205–12. https://doi.org/10.4103/0970-9290.183121
2. Ahmed FT, Aljeuary MT. The strategy of delayed reconstruction of the mandible in war injuries. *J Craniofac Surg* 2017; **28**:826–30. https://doi.org/10.1097/SCS.0000000000003447
3. Rustemeyer J, Siegmund BJ, Okcu Y, Busch A. Total mandibular reconstruction following diffuse sclerosing osteomyelitis. *Oral Maxillofac Surg* 2019; **23**:95–9. https://doi.org/10.1007/s10006-018-0731-9
4. Riley RW, Powell NB, Guilleminault C, Ware W. Obstructive sleep apnea syndrome following surgery for mandibular prognathism. *J Oral Maxillofac Surg* 1987;**45**:450–2. https://doi.org/10.1016/0278-2391(87)90016-4
5. Brennick MJ, Gefter WB, Margulies SS. Mechanical effects of genioglossus muscle stimulation on the pharyngeal airway by MRI in cats. *Respir Physiol Neurobiol*

2007;**156**:154–64. https://doi.org/10.1016/j.resp.2006.08.010

6. Cai TY, Zhang WB, Yu Y, Wang Y, Mao C, Guo CB, Yu GY, Peng X. Scoring system for selective tracheostomy in head and neck surgery with free flap reconstruction. *Head Neck* 2019;**42**:476–84. https://doi.org/10.1002/hed.26028
7. Flint PW, Haughey BH, Lund VJ, Niparko JK, Robbins KT, Thomas JR, Lesperance MM. *Cummings otolaryngology—head and neck surgery*. Sixth edition *Part II, Chapter 7* Saunders; 2015. p. 95–102.
8. Das P, Zhu H, Shah RK, Roberson DW, Berry J, Skinner ML. Tracheotomy-related catastrophic events: results of a national survey. *Laryngoscope* 2012;**122**:30–7. https://doi.org/10.1002/lary.22453
9. Coyle MJ, Tyrrell R, Godden A, Hughes CW, Perkins C, Thomas S, Godden D. Replacing tracheostomy with overnight intubation to manage the airway in head and neck oncology patients: towards an improved recovery. *Br J Oral Maxillofac Surg* 2013;**51**:493–6. https://doi.org/10.1016/j.bjoms.2013.01.005
10. Tideman H. Fibula free flap: a new method of mandible reconstruction. *Plast Reconstr Surg* 1990;**84**:71–9. https://doi.org/10.1097/00006534-198907000-00014
11. Moubayed S, Barker D, Razfar A, Nabili V, Blackwell K. Microvascular reconstruction of segmental mandibular defects without tracheostomy. *Otolaryngol Head Neck Surg* 2015;**152**:250–4. https://doi.org/10.1177/0194599814556625
12. Jewer DD, Boyd JB, Manktelow RT, Zuker RM, Rosen IB, Gullane PJ, Rotstein LE, Freeman JE. Orofacial and mandibular reconstruction with the iliac crest free flap: a review of 60 cases and a new method of classification. *Plast Reconstr Surg* 1989;**84**:391–403. https://doi.org/10.1097/00006534-198909000-00001
13. Flemons WW. Obstructive sleep apnea. *N Engl J Med* 2002;**347**:498–504. https://doi.org/10.1056/NEJMcp012849
14. Denny AD, Talisman R, Hanson PR, Recinos RF. Mandibular distraction osteogenesis in very young patients to correct airway obstruction. *Plast Reconstr Surg* 2001;**108**:302–11. https://doi.org/10.1097/00006534-200108000-00004
15. Ogutcen-Toller M, Sarac YS, Cakír-Ozkan N, Sarac D, Sakan B. Computerized tomographic evaluation of effects of mandibular anterior repositioning on the upper airway: a pilot study. *J Prosthet Dent* 2004;**92**:184–9. https://doi.org/10.1016/j.prosdent.2004.05.003
16. Choi JK, Hur YK, Lee JM, Clark GT. Effects of mandibular advancement on upper airway dimension and collapsibility in patients with obstructive sleep apnea using dynamic upper airway imaging during sleep. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2010;**109**:712–9. https://doi.org/10.1016/j.tripleo.2009.11.034
17. Ma SYL, Whittle T, Descallar J, Murray GM, Darendeliler MA, Cistulli P, Dalci O. Association between resting jaw muscle electromyographic activity and mandibular advancement splint outcome in patients with obstructive sleep apnea. *Am J Orthod Dentofacial Orthop* 2013;**144**:357–67. https://doi.org/10.1016/j.ajodo.2013.04.015
18. Kurtulmus H, Cotert S, Bilgen C, On AY, Boyacioglu H. The effect of a mandibular advancement splint on electromyographic activity of the submental and masseter muscles in patients with obstructive sleep apnea. *Int J Prosthodont* 2009;**22**:586–93.
19. Johal A, Gill G, Ferman A, McLaughlin K. The effect of mandibular advancement appliances on awake upper airway and masticatory muscle activity in patients with obstructive sleep apnoea. *Clin Physiol Funct Imaging* 2007;**27**:47–53. https://doi.org/10.1111/j.1475-097X.2007.00714.x
20. Gholinia F, Habibi L, Amrollahi Boyouki M. Cephalometric evaluation of the upper airway in different skeletal classifications of jaws. *J Craniofac Surg* 2019;**30**:e469–74. https://doi.org/10.1097/SCS.0000000000005637
21. Hayden RE, Mullin DP, Patel AK. Reconstruction of the segmental mandibular defect: current state of the art. *Curr Opin Otolaryngol Head Neck Surg* 2012;**20**:231–6. https://doi.org/10.1097/MOO.0b013e328355d0f3
22. Castling B, Telfer M, Avery BS. Complications of tracheostomy in major head and neck cancer surgery; a retrospective study of 60 consecutive cases. *Br J Oral Maxillofac Surg* 1994;**32**:3–5. https://doi.org/10.1016/0266-4356(94)90162-7
23. Halfpenny W, McGurk M. Analysis of tracheostomy-associated morbidity after operations for head and neck cancer. *Br J Oral Maxillofac Surg* 2000;**38**:509–12. https://doi.org/10.1054/bjom.2000.0310
24. Cameron M, Corner A, Diba A, Hankins M. Development of a tracheostomy scoring system to guide airway management after major head and neck surgery. *Int J Oral Maxillofac Surg* 2009;**38**:846–9. https://doi.org/10.1016/j.ijom.2009.03.713
25. Gibson J, Smith K, Rennie M. Prevention of disuse muscle atrophy by means of electrical stimulation: maintenance of protein synthesis. *Lancet* 1988;**2**:767–70. https://doi.org/10.1016/s0140-6736(88)92417-8
26. Du W, He D, Wang Y, Liu H, Liao C, Fei W, Luo E. Upper airway changes after mandibular setback and/or advancement genioplasty in obese patients. *J Oral Maxillofac Surg* 2017;**75**:2202–10. https://doi.org/10.1016/j.joms.2017.04.012
27. Nagy J, Braunitzer G, Antal M, Berkovits C, Novák P, Nagy K. Quality of life in head and neck cancer patients after tumor therapy and subsequent rehabilitation: an exploratory study. *Qual Life Res* 2014;**23**:135–43. https://doi.org/10.1007/s11136-013-0446-1

Correspondence to: Peking University School and Hospital of Stomatology
No. 22
Zhongguancun South Avenue
Haidian District
Beijing 10081
China.
E-mail: pxpengxin@263.net