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Postoperative complications after bimaxillary orthognathic surgery: A retrospective study with focus on postoperative ventilation strategies and posterior airway space (PAS)

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ABSTRACT

Purpose: The aim of this study was to evaluate the impact of extubation time on postoperative complications in patients undergoing bimaxillary orthognathic surgery. We therefore retrospectively compared the effect of early extubating (EE) in the operating room versus delayed extubating (LE) on the intensive care unit (ICU) regarding postoperative complications and length of ICU/hospital stay (LOICUS/LOHS). Furthermore, we analyzed the influence of the PAS change on postoperative complications.

Methods: The clinical data of 117 patients were retrospective analyzed regarding postoperative complications using Clavian–Dindo Classification. Volumetric calculations of the pre- and postoperative PAS were conducted using ITK-SNAP software. The Fisher's exact test was performed to evaluate the significance of differences between categorical variables. Continuous variables were analyzed using the Mann–Whitney U-Test or the Kruskal–Wallis one-way analysis of variance. Regression analysis was used estimating predictors for postoperative complications.

Results: EE led to significant shortening of LOICUS ($p < 0.001$) and LOHS ($p = 0.023$). In total, we recorded 38 complications (minor $n = 30$; major $n = 8$) within the hospital stay. Complication rates were without significant differences with respect to the postoperative ventilation strategy. Large changes in PAS volume led to an increase in the major complication rates ($p = 0.031$). Increase or decrease of PAS was independent from postoperative complication rates ($p = 1.000$). Higher body mass index ($p = 0.04$) and a higher ASA PS score ($p = 0.016$) were associated with increased major complication rates.

Conclusion: Early extubation after surgery is a safe procedure and is associated with a reduced LOICUS and LOHS. Complications seem to occur more frequently in marked changes of the PAS and should be considered in perioperative risk stratification.

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1. Introduction

Orthognathic surgery is a standardized surgical procedure for the correction of dentofacial anomalies (Monson, 2013; Eshghpour et al., 2018). The movement of skeletal structures leads to a change in the soft tissues such as the submental and nasolabial region with

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a significant influence on the facial aesthetics (Chasseimi et al., 2014). Volumetric alterations of the posterior airway space (PAS) after bimaxillary orthognathic surgery (BOS) can be a risk factor for airway disorder (Gokce et al., 2012, 2014). Especially for patients with reduced preoperative PAS or obstructive sleep apnea syndrome orthognathic surgery may both improve and worsen respiratory function (Gokce et al., 2012; Raunio et al., 2012; Raffaini et al., 2013; Tepecik et al., 2018).

Besides experienced surgical care, adequate perioperative airway management is an important component for the successful execution of complex orthognathic reconstruction (Posnick et al., 2016).

The preoperative radiological diagnosis by cone beam CT (CB-CT) allows not only the visualization of bony structures, but also the three-dimensional analysis of the airway morphology, and is superior to the two-dimensional analysis of posterior airway space using lateral cephalometry (Park et al., 2006; Ayoub et al., 2019).

The purpose of this retrospective study was to evaluate the impact of extubation time on postoperative complications in patients undergoing BOS. We therefore compared the effect of early extubating (EE) in the operating room versus delayed extubating (LE) on the intensive care unit (ICU) regarding postoperative complications and length of ICU/hospital stay (LOICUS/LOHS). Additionally, we analyzed associations between PAS volume alterations, jaw movement and the incidence of postoperative complications in order to refine perioperative strategies.

2. Material and methods

2.1. Patients

This retrospective study was approved by the local ethics committee (No. 19–1101) of the University Hospital of Cologne, Germany, and conducted in accordance with the ethical principles of the declaration of Helsinki. A total of 117 patients were included in the study. Data analysis was performed retrospectively and included patients undergoing BOS between February 2012 and April 2018 at the Department of Oral and Craniomaxillofacial and Plastic Surgery at the University Hospital of Cologne. All BOS patients underwent Le Fort I osteotomy in the upper jaw and a bilateral sagittal split ramus osteotomy in the lower jaw. Patients were subdivided according to the Angle classification. Class III patients received maxillary osteotomy and mandibular setback surgery, while Class II patients underwent maxillomandibular advancement. Genioplastics were performed at the time of removal of the osteosynthesis material and thus independently of the postoperative CB-CT evaluation. Patients with recent trauma, active malignant or inflammatory diseases, as well as nasogastric tubes at postoperative CB-CT scan were excluded from the study.

2.2. Treatment

Considering the increased risk of upper airway swelling and requirement for postoperative maxillo-mandibular fixation, all patients were monitored postoperatively on the ICU. Depending on the postoperative ventilation strategy, patients were divided into two groups (EE vs LE). Data analysis included skeletal discrepancy, extent of maxillary and mandibular movement, PAS volume and red blood cell (RBC) count before and after surgery, sex, age, American Society of Anesthesiologists physical status (ASA PS) classification and Body Mass Index (BMI). Clavien–Dindo (CD) Classification was used for grading of the postoperative complications (Umezawa et al., 2016; Wang et al., 2018). Due to the retrospective design all cases were reviewed in the electronic hospital database. Based on the CD Classification, all deviations from the normal postoperative course were detected. Grading was performed by two independent medical doctors (MR, VS). Nonconforming results were reevaluated. Minor complications were defined as CD grades I and II, major complications were defined as CD grades III–V.

2.3. Segmentation of the posterior airway space

111 of 117 patients were selected retrospectively for segmentation of the PAS. All of these patients received preoperative CB-CT during orthodontic-surgical consultation and post-operative CB-CT during inpatient stay after BOS. CB-CTs of 6 patients were not included for segmentation because of insufficient image quality.

CB-CTs were taken with the GALILEOS Comfort® cone-beam CT (Sirona, Bensheim, Germany) at 85 kV, 28 mA/s, a scan time of 14s and a field of view measures 15 cm according to a standardized examination protocol. Three-dimensional images composed of 512³ isotropic voxels with a resolution of 300 µm or 2.5 line pairs/mm were obtained. Images enabled visualization of the posterior airway space in the sagittal, axial and coronal plane.

Semiautomatic segmentation has been confirmed as a reliable, valid, and time efficient method to analyze three-dimensional and morphological changes of the posterior airway (Alsufyani et al., 2016). ITK-SNAP (Version 3.6.0, Penn Image Computing and Science Laboratory, University of Pennsylvania, Philadelphia, USA) was used for the volumetric calculation of the PAS for each individual patient (Yushkevich et al., 2006). Initially used for brain morphometry, ITK-SNAP is a validated tool for multiple three-dimensional segmentation studies (Dade et al., 2004; Yushkevich et al., 2016; Kauke et al., 2018a, b; Gibelli et al., 2019).

The determination of the anatomical boundaries calculating PAS were based on the methods described by Ayoub et al. (2019). The cranial margin of the PAS was defined by the palatal plane perpendicular to the sagittal plane passing through the anatomical landmarks spina nasalis anterior and spina nasalis posterior. The inferior border has been set as a parallel plane to the palatal plane which passes through the tip of the epiglottis (Ayoub et al., 2019). After previous manual delineation and image navigation, virtual bubbles were placed following the active contour of the PAS until the segmentation process was completed. Volume of the PAS for each patient was graphically displayed and automatically calculated in cubic millimeters (mm³) as previously described (Yushkevich et al., 2006).

2.4. Jaw movement

Spatial landmarks were set before measuring mandibular and maxillary movement distances as described previously (Cevidanes et al., 2009; Brunetto et al., 2014; Souza Pinto et al., 2019). Upper and lower jaw movements were measured linearly in the sagittal plane (Souza Pinto et al., 2019). After determining the points Maxilla (A), Mandible (B), Menton (Me) and Posterior Nasal Spine (PNS), the distance of these points to a horizontal (HRL) and a vertical reference line (VRL) was measured. HRL is parallel to the Frankfurt horizontal plane (FHP) and passes through the bony center of the Sella turcica (S). VRL is perpendicular to HRL and also passes through S. Subsequent four vertical (V–A, V–PNS, V–B, V–Me) and four horizontal (H–A, H–PNS, H–B, H–Me) measurements were made. This resulted in eight preoperative and eight postoperative measurements for each patient. The difference between pre- and postoperative measurements in each case reflects the extent of jaw movement.

2.5. Statistical analysis

Statistical analysis was performed using SPSS (IBM SPSS 25.0, IBM Corp.; Armonk, NY, USA). The Fisher's exact test was performed to evaluate differences between categorical variables. Continuous variables were analyzed using the Mann–Whitney U-Test or the Kruskal–Wallis one-way analysis of variance. Wilcoxon signed-rank test was used to compare matched samples. Univariate Regression analysis was performed for estimating predictors for postoperative complications. P-values less than 0.05 were considered statistically significant.

Table 1
Patients characteristics and clinical findings.

Characteristics	EE (n = 38)	LE (n = 79)	p-value
	Mean \pm SD [range] or n (%)	Mean \pm SD [range] or n (%)	
Age (years)	23.9 \pm 6.209 [16–44]	22.8 \pm 6.244 [16–53]	p = 0.230
Female sex	22 (57.9%)	50 (63.3%)	p = 0.685
BMI (kg/m ²)	23.1 \pm 3.106 [17–29]	23.2 \pm 3.874 [18–36]	p = 0.500
ASA PS			p = 0.209
ASA I	22 (57.9%)	56 (70.9%)	
ASA II	16 (42.1%)	23 (29.1%)	
Angle classification			p = 0.341
Angle Class II	5 (13.2%)	14 (17.7%)	
Angle Class III	26 (68.4%)	58 (73.4%)	
Neither Class II nor III	7 (18.4%)	7 (8.9%)	
Clinical findings			
Length of hospital stay (days)	7.11 \pm 1.060 [4–8]	8.10 \pm 2.453 [5–21]	p = 0.023
Length of ICU stay (days)	1.05 \pm 0.226 [1–2]	2.28 \pm 2.224 [1–15]	p \leq 0.001
RBC count before surgery (g/dl)	12.76 \pm 1.536 [10–16]	12.48 \pm 1.361 [9–16]	p = 0.368
RBC count after surgery (g/dl)	10.41 \pm 1.554 [7–13]	9.522 \pm 1.782 [6–14]	p = 0.006

EE: early extubating in the operating room; LE: delayed extubating at the intensive care unit; BMI: Body Mass Index; ASA PS: American Society of Anesthesiologists Physical Status Classification System; RBC: Red blood cell.

3. Results

In the study 117 patients with a mean age of 23.2 \pm 6.2 years were included. Angle class III was found in 84 (71.8%), class II in 19 (16.2%) individuals. No skeletal class could be specified in 14 patients (12.0%). Baseline characteristics regarding the two extubation strategies (EE and LE) are summarized in Table 1. The two groups were similar with respect to demographic and clinical characteristics.

The postoperative ventilation strategy was significantly associated with the length of ICU and length of hospital stay. EE led to significant shortening of ICU (p < 0.001) and hospital stay (p = 0.023). The postoperative red blood cell (RBC) count differed in the two treatment groups. Early extubated patients showed a significantly higher RBC value (p = 0.006). Length of stay and RBC

Table 2
Complications in detail according to the Clavian-Dindo Classification.

Quantity	Group	CD Grade	Complication	Treatment
1	EE	Grade I	Venous thrombosis	Physiotherapy, without pharmacological or surgical treatment
2	EE	Grade I	Nausea and vomiting	Pharmacological treatment, MMF removal
1	LE	Grade I	Nausea and vomiting	Pharmacological treatment, MMF removal
1	LE	Grade I	Unintended extubation (by patient)	Non-pharmacological treatment without need for re-intubation
1	LE	Grade I	Difficult airway situation	Surgical standby (in case of the need for tracheostomy)
1	EE	Grade II	Anemia	Blood transfusion
9	LE	Grade II	Anemia	Blood transfusion
4	EE	Grade II	Dyspnea/respiratory distress	Pharmacological and non-pharmacological treatment
3	LE	Grade II	Dyspnea/respiratory distress	Pharmacological and non-pharmacological treatment
1	LE	Grade II	Allergic reaction	Pharmacological and non-pharmacological treatment
1	LE	Grade II	Postoperative cognitive dysfunction	Pharmacological and non-pharmacological treatment
1	LE	Grade II	Wound infection	Pharmacological (antibiotic) treatment
2	LE	Grade II	Epistaxis	Pharmacological and non-pharmacological treatment
2	LE	Grade II	Postoperative coagulopathy	Pharmacological and hemostatic treatment
1	LE	Grade IIIa	Pulmonary embolism	Radiological and pharmacological treatment not under general anesthesia
1	LE	Grade IIIb	Anatomical malposition	Surgical revision under general anesthesia
1	EE	Grade IIIb	Postoperative bleeding/hemorrhage	Surgical revision under general anesthesia
1	EE	Grade IVa	Respiratory dysfunction/bleeding	Endotracheal re-intubation and surgical intervention under general anesthesia
3	LE	Grade IVa	Respiratory/pulmonary dysfunction	Endotracheal re-intubation and mechanical ventilation
1	LE	Grade IVa	Respiratory/pulmonary dysfunction	Tracheotomy and mechanical ventilation

EE: early extubating in the operating room; LE: delayed extubating at the intensive care unit; CD: Clavian-Dindo Classification; MMF: maxillo-mandibular fixation.

course are shown in Table 1. In total, we recorded 38 complications (minor n = 30; major n = 8) within the hospital stay. Complications and grading results are summarized in detail in Table 2. According to the CD grading score, major complications included pulmonary embolism with the need for radiological and pharmacological treatment not under general anesthesia (n = 1), surgical revision under general anesthesia (n = 2), respiratory dysfunction resulting in altered gas exchange with need for endotracheal re-intubation and mechanical ventilation (n = 5). Complication rates were without significant differences in the two groups (Table 3). Higher BMI (p = 0.04) and ASA PS class II (p = 0.016) were significantly associated with an increase in major complications. Mean jaw measurements and PAS volume changes are shown in Table 4. Measurements indicate a setback of the mandible in combination with maxillary advancement in class III patients, whereas class II patients received mandibular advancement and maxillary setback. Subsequently, BOS caused changes in PAS: an increase of PAS was observed in 67 patients (57.3%), whereas a reduction of PAS was found in 44 patients (37.6%). Pre-to postoperative PAS volume changes were significantly associated with complication rates after BOS. The occurrence of major complications is associated with larger PAS volume changes (p = 0.031, Fig. 1). Increase or decrease of PAS was independent from complication rates (p = 1.000). There was no significant correlation between PAS volume changes and the extent of jaw movement (Table 5).

Univariate regression analysis estimating predictors for postoperative complications verified significant associations for higher BMI and ASA PS class II patients. Angle classification, sex, age and RBC count were not significantly associated with postoperative complications (Table 6).

4. Discussion

BOS is an established surgical procedure for the correction of dysgnathia (Monson, 2013). Nevertheless, it is still an elective operation and a challenging procedure even for the experienced surgeon requiring close cooperation with the anesthesiologist not only because of the close proximity to the airways (Kim, 2017a). Maxillary-mandibular fixation (MMF) prior to extubation requires increased perioperative attention from the entire team. Due to the MMF and a suspected respiratory tract swelling, patients are often extubation-delayed on the ICU.

Table 3
Complication rates associated with the postoperative ventilation strategy using the Clavian-Dindo classification.

Clavian-Dindo Grade	EE (n = 38)	LE (n = 79)	p-value
Minor			
I	3 (7.9%)	3 (3.8%)	
II	5 (13.2%)	19 (24.1%)	
Minor complications	8 (21.1%)	22 (27.8%)	p = 0.503
Major			
III	1 (2.6%)	2 (2.5%)	
IV	1 (2.6%)	4 (5.1%)	
V	0	0	
Major complications	2 (5.3%)	6 (7.6%)	p = 1.000
Overall complications	10 (26.3%)	28 (35.4%)	p = 0.401

EE: early extubating in the operating room, LE: delayed extubating at the intensive care unit.

In this study we evaluated the effect of extubation time on postoperative complications in patients undergoing BOS. We were able to show that EE leads to a significant shortening of LOICUS and LOHS. Our study confirms the results of Posnick et al., who showed that 96% of examined patients undergoing bimaxillary surgery were extubated safely in the operating room (Posnick et al., 2016). However, in comparison to our results, Posnick et al. did not compare postoperative complications of patients who were extubated later in the ICU with patients who had already been extubated earlier.

Interestingly, most complications in bimaxillary orthognathic surgery arise early after the operation (Kantar et al., 2018). If complications occur, they may either be respiratory tract related or due to the operation. Our results indicate that EE does not increase the complication rate. Thus, EE seems to be a safe procedure, which significantly reduces the length of ICU and hospital stay.

Consistent with other studies, an increased BMI is a risk factor in orthognathic surgery and correlates significantly with an increase in postoperative complications (Lye, 2008; Kobayashi et al., 2013; van der Vlis et al., 2014). In contrast, Thastum et al. showed that decreasing BMI may go in line with relative increase in intraoperative blood loss (Thastum et al., 2016). The increase in complication rates in patients with a higher ASA PS score reflects the importance of concomitant diseases and should be taken into account in the preoperative risk assessment.

In addition to the major complications, minor complication analysis emphasizes the need for intensified postoperative care regardless of the postoperative ventilation strategy.

BOS inevitably leads to a change in the upper airways and the PAS (Choi et al., 2014; Lee et al., 2017). Therefore, we tested the hypothesis that alterations in PAS affected postoperative complications. Even if patients underwent mandibular setback surgery, in the majority of the examined patients, an increase of the PAS after the operation was observed. These findings coincide with other studies (Gokce et al., 2014; Souza Pinto et al., 2019). Interestingly, the reduction of the PAS did not increase the complication rate.

Table 4
Jaw movement and PAS volume in skeletal classes.

		pre-OP Mean ± SD [range]	post-OP Mean ± SD [range]	p-value
Angle Class III (n=79)				
Jaw movement (mm)	H-A	63.45 ± 5.54 [49–80]	66.09 ± 5.85 [53–86]	p ≤ 0.001
	H-PNS	18.17 ± 4.12 [9–37]	21.12 ± 4.28 [13–39]	p ≤ 0.001
	H-B	65.57 ± 9.05 [37–89]	63.78 ± 8.00 [47–87]	p = 0.005
	H-ME	63.18 ± 10.38 [33–89]	62.11 ± 9.66 [42–92]	p = 0.136
	V-A	47.14 ± 4.29 [37–58]	45.18 ± 4.91 [32–55]	p ≤ 0.001
	V-PNS	40.72 ± 3.70 [32–48]	38.32 ± 4.53 [24–48]	p ≤ 0.001
	V-B	89.27 ± 7.53 [72–112]	85.90 ± 7.25 [73–104]	p ≤ 0.001
	V-ME	107.19 ± 10.16 [62–132]	106.06 ± 8.22 [88–130]	p = 0.001
PAS volume (mm ³)		16941.34 ± 7871.67 [3636–44230]	18185.85 ± 7644.34 [6608–52030]	p = 0.042
Angle Class II (n=19)				
Jaw movement (mm)	H-A	65.33 ± 4.97 [58–81]	64.90 ± 5.21 [55–77]	p = 0.747
	H-PNS	17.86 ± 3.78 [11–26]	18.38 ± 5.08 [8–28]	p = 0.472
	H-B	51.27 ± 9.49 [35–75]	54.48 ± 8.01 [36–68]	p = 0.036
	H-ME	44.73 ± 12.85 [23–72]	48.75 ± 11.17 [23–65]	p = 0.044
	V-A	47.55 ± 4.54 [38–53]	45.13 ± 5.87 [37–60]	p = 0.003
	V-PNS	40.99 ± 3.95 [34–49]	39.27 ± 4.95 [32–51]	p = 0.091
	V-B	86.31 ± 9.87 [68–101]	84.96 ± 8.56 [70–102]	p = 0.212
	V-ME	104.07 ± 9.38 [88–121]	103.86 ± 8.52 [91–121]	p = 0.931
PAS volume in mm ³		13880.11 ± 6255.66 [6688–31160]	16864.63 ± 7378.88 [5828–32800]	p = 0.147
Neither Class II nor III (n=14)				
Jaw movement (mm)	H-A	62.67 ± 5.78 [55–72]	65.22 ± 6.52 [56–78]	p = 0.019
	H-PNS	18.79 ± 5.35 [12–28]	21.02 ± 6.10 [13–31]	p = 0.008
	H-B	58.88 ± 6.57 [47–69]	59.19 ± 8.52 [46–75]	p = 0.802
	H-ME	56.26 ± 8.26 [44–71]	56.60 ± 10.69 [38–79]	p = 0.950
	V-A	47.67 ± 4.44 [40–54]	46.55 ± 3.55 [42–52]	p = 0.510
	V-PNS	40.50 ± 4.61 [32–48]	41.60 ± 5.31 [34–49]	p = 0.158
	V-B	87.34 ± 8.34 [70–105]	86.69 ± 7.45 [69–93]	p = 0.683
	V-ME	107.17 ± 8.51 [91–125]	107.00 ± 8.78 [89–118]	p = 0.875
PAS volume in mm ³		16776.43 ± 7623.66 [9050–34460]	15228.14 ± 6056.96 [6833–25400]	p = 0.510

H-A: Horizontal (H) distance from point Maxilla (A) to vertical reference line (VRL).
 H-PNS: Horizontal (H) distance from point posterior nasal spine (PNS) to vertical reference line (VRL).
 H-B: Horizontal (H) distance from Mandible (M) to vertical reference line (VRL).
 H-ME: Horizontal (H) distance from Menton (ME) to vertical reference line (VRL).
 V-A: Vertical (V) distance from point Maxilla (A) to horizontal reference line (VRL).
 V-PNS: Vertical (V) distance from point posterior nasal spine (PNS) to horizontal reference line (VRL).
 V-B: Vertical (V) distance from Mandible (M) to horizontal reference line (VRL).
 V-ME: Vertical (V) distance from Menton (ME) to horizontal reference line (VRL).
 PAS: posterior airway space.

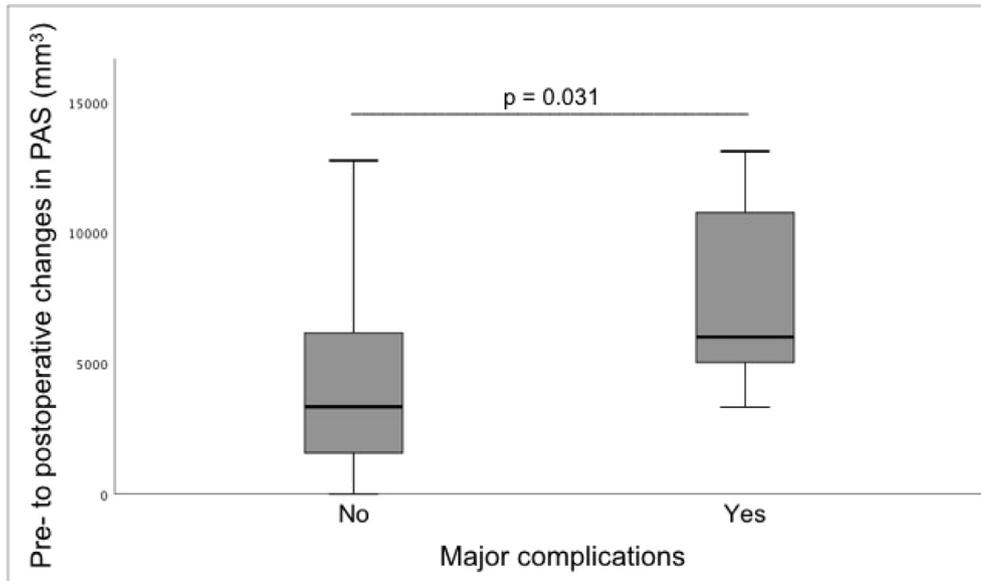


Fig. 1. Pre- to postoperative changes in PAS volume (mm³) with and without major complications.

Table 5
Association between jaw movement and posterior airway space.

	jaw movement difference pre-OP/post-OP							
	H-A	H-PNS	H-B	H-ME	V-A	V-PNS	V-B	V-Me
Angle Class III (n=79)								
PAS difference pre-OP/post-OP								
correlation coefficient	0.056	0.024	-0.053	-0.103	-0.081	0.064	0.063	-0.073
p-value	0.625	0.834	0.642	0.365	0.480	0.576	0.578	0.524
Angle Class II (n=19)								
PAS difference pre-OP/post-OP								
correlation coefficient	-0.103	-0.115	0.441	0.281	-0.074	0.359	-0.274	0.268
p-value	0.675	0.640	0.059	0.244	0.764	0.131	0.256	0.268
Neither Class II nor III (n=14)								
PAS difference pre-OP/post-OP								
correlation coefficient	0.220	0.130	-0.275	-0.371	0.470	0.412	0.377	0.439
p-value	0.450	0.657	0.341	0.191	0.090	0.143	0.184	0.116
Overall PAS difference (n=112)								
correlation coefficient	0.031	0.011	0.051	-0.011	-0.030	0.167	0.018	-0.022
p-value	0.748	0.907	0.594	0.911	0.752	0.079	0.847	0.817

H-A: Horizontal (H) distance from point Maxilla (A) to vertical reference line (VRL).
H-PNS: Horizontal (H) distance from point posterior nasal spine (PNS) to vertical reference line (VRL).
H-B: Horizontal (H) distance from Mandible (M) to vertical reference line (VRL).
H-ME: Horizontal (H) distance from Menton (ME) to vertical reference line (VRL).
V-A: Vertical (V) distance from point Maxilla (A) to horizontal reference line (VRL).
V-PNS: Vertical (V) distance from point posterior nasal spine (PNS) to horizontal reference line (VRL).
V-B: Vertical (V) distance from Mandible (M) to horizontal reference line (VRL).
V-ME: Vertical (V) distance from Menton (ME) to horizontal reference line (VRL).
PAS: posterior airway space.

Table 6
Univariate regression analysis for major complications.

	OR	95% CI	p-value
Sex	0.358	0.047–2.726	0.321
Age	0.997	0.893–1.113	0.960
BMI	1.224	1.014–1.477	0.036
ASA PS classification	6.751	1.155–39.468	0.034
RBC count (pre-op)	0.590	0.293–1.186	0.138
Angle classification			
Angle Class II	0.266	0.017–4.103	0.343
Angle Class III	0.309	0.044–2.147	0.235

OR: Odds ratio; CI: confidence interval; BMI: Body Mass Index; ASA PS: American Society of Anesthesiologists Physical Status Classification System; RBC: Red blood cell.

However, we found an increase of serious complications, when surgical procedure results in a large volume change of the PAS.

The increased complication rate associated with an increasing volume difference of the PAS could potentially be related to greater surgical trauma due to large movement distances of the jaws. A recent study was able to show that increasing complication rates can also be related to certain types of jaw movements, such as maxillary setback with impaction (Eshghpour et al., 2018). Although Choi et al. demonstrated that the extent of mandibular setback in class III patients correlates with decreased airway space (Choi et al., 2014), to our knowledge, there is currently no study investigating the alteration of the PAS with respect to severe complications. However, it appears that a large amount of mandibular setback, obesity, and potential sleep-disordered

breathing may lead to obstructive sleep apnea syndrome in the future (Chen et al., 2007; Kitagawara et al., 2008). Early complications such as severe bleeding requiring operative revision can be triggered by extensive surgery and may be associated with an extended change in the PAS (Thastum et al., 2016). With regard to respiratory failure, potential postoperative problems can be reduced by predicting the risk of respiratory failure and determining the appropriate amount of setback (Kim, 2017b). Hence, all patients in our study were screened for a potentially narrowed PAS preoperatively using cephalograms and CB-CTs.

In summary, several biasing factors make it difficult to draw conclusions about the development of the PAS based on the distance of the maxillary advancement in mm (Santagata et al., 2015). The results of our study further suggest that predicting the change in PAS due to the jaw movement is limited (Table 5). Individual bleeding diathesis, postoperative swelling, adaptive processes of soft tissue structures and complex bony anatomy could complicate the accurate prediction of possible postoperative complications (Chen et al., 2007; Posnick et al., 2016).

This study is limited because of its retrospective study design. Another limitation is the small sample of patients, especially with regard to the class II patients. Further investigations are requested analyzing the impact of airway space alterations on postoperative complications.

5. Conclusion

In this study, we show that the early extubation of BOS patients in the operating room is not associated with an increased complication rate. Early extubation after surgery is a safe procedure and is also associated with a significantly reduced length of ICU and hospital stay. The reduction of the PAS does not increase postoperative complications. A strict indication should be given if an extensive displacement of the jaw is planned, which may be accompanied by a marked change in the PAS, because serious complications may occur more frequently.

Ethical approval

This present retrospective study was approved by the Ethics Committee of the Medical Faculty of the University of Cologne (No. 19–1101) and performed in accordance to the 1964 Declaration of Helsinki and its later amendments.

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Conflicts of interest

The authors declare no conflict of interest.

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