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Postoperative nausea and vomiting following orthognathic and temporomandibular joint surgery: a prospective two-center cohort study

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This study comprehensively analyzes the incidence and risk factors of postoperative nausea and vomiting(PONV) following orthognathic and temporomandibular joint(TMJ) surgeries. We evaluate the applicability of the Apfel score and personalized risk prediction models in this context to establish an evidence-based foundation for PONV prevention strategies in these surgical patients. This multicenter prospective cohort study enrolled 388 eligible participants who underwent orthognathic or TMJ surgery at West China Hospital of Stomatology (WCCHS) and Peking University Shenzhen Hospital (PUSZH) from April 2025 to June 2025, based on predefined inclusion/exclusion criteria. The WCCHS cohort (April 2025-June 2025; $n = 303$) served as the training set, while the PUSZH cohort (same period; $n = 85$) functioned as an external validation set. Independent predictors were identified using Least Absolute Shrinkage and Selection Operator(LASSO)regression, followed by the development of a risk prediction model through logistic regression. The Area Under the Receiver Operating Characteristic Curve（AUC）differences between the Apfel risk score and personalized prediction model were then compared across both datasets. The incidence of PONV following orthognathic and TMJ surgery was 58.25%. Significant predictors included female gender, non-smoker, postoperative opioids, and surgical approach (all $P < 0.05$). The Apfel score achieved an AUC of 0.62 (95% CI: 0.56–0.68) for PONV prediction in this cohort. However, it was significantly outperformed by our novel risk prediction model, which achieved an AUC of 0.73 ($P < 0.001$) in the training set and an AUC of 0.71 ($P = 0.005$) in the validation set. Independent predictors for PONV in orthognathic and TMJ surgery patients included: female gender, non-smoker, postoperative opioids, surgical approach, ASA physical status, family history of motion sickness, and a history of PONV. Therefore, incorporating the specific predictors identified in this study into the Apfel score enhances the predictive performance of the new model for PONV risk in this patient population. Patients undergoing orthognathic and TMJ surgery exhibit a high incidence of PONV. Incorporating specific predictors into the Apfel score enhances PONV prediction accuracy in this population, thereby informing evidence-based prophylaxis.

Keywords Postoperative nausea and vomiting, Orthognathic surgery, Temporomandibular joint surgeries, Apfel score

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Postoperative nausea and vomiting (PONV) typically occur within the first 24 h after surgery. Key manifestations include nausea, vomiting, and retching – representing acute gastrointestinal disturbances. Although PONV typically resolves spontaneously within 24 h, a small proportion may experience PONV lasting 3–5 days or longer[1,2]. Current evidence indicates PONV incidence ranges from 20% to 37% in general surgery[3], compared to 21.1–75% in oral and maxillofacial surgery (OMS). This burden is particularly pronounced following orthognathic and temporomandibular joint (TMJ) procedures[4,5]. PONV exacerbates patient distress and may lead to serious complications, including fluid-electrolyte imbalances, wound dehiscence, aspiration, and delayed recovery[6,7]. Consequently, it prolongs hospitalization and increases healthcare costs[8].

PONV arises from multifactorial interactions, including patient characteristics, anesthetic techniques, and surgical procedures[9,10]. Apfel et al.[11]established four independent predictors: female gender, non-smoker, a history of PONV/motion sickness, and postoperative opioids. Evidence suggests increased susceptibility in patients aged < 50 years[12]. In contrast, Koivuranta[13] risk score incorporates greater complexity. It expands the Apfel score by integrating a set of five risk factors, including surgical duration. These factors are assigned specific weights and are summed to yield a composite predictive score. Consequently, the simpler Apfel score remains widely adopted in surgical and anesthetic practice, with robust validation across diverse populations[14,15]. However, its applicability to orthognathic and TMJ surgery cohorts remains inadequately studied. Addressing PONV in this specialized surgical population represents an ongoing clinical challenge[16].

We hypothesize that female gender, postoperative opioids, non-smoker, history of motion sickness/PONV, ASA physical status, and surgical approach collectively enable the development of an effective specialty-specific PONV prediction model for orthognathic and TMJ surgery. Using a multicenter prospective cohort design, this study aims to: (1) identify procedure-specific PONV risk factors; (2) systematically evaluate the Apfel score's clinical applicability in this population. Results will establish an evidence base for precision prophylaxis strategies in orthognathic and TMJ surgery, thereby reducing PONV incidence and associated complications.

Methods

Study design and participants

This multicenter prospective cohort study consecutively enrolled patients undergoing orthognathic or TMJ surgery at West China Hospital of Stomatology (WCCHS) and Peking University Shenzhen Hospital (PUSZH) from April 2025 to June 2025. All received balanced intravenous-inhalational anesthesia and standardized antiemetic prophylaxis per the Fourth PONV Consensus Guidelines[2]. Inclusion criteria: (1) Hospitalization ≥ 24 h; (2) Isolated orthognathic or TMJ procedures. Exclusion criteria: (1) Concurrent non-maxillofacial surgery; (2) Migraine, neurological or gastrointestinal disorders; (3) Local anesthesia. Standard postoperative ward care was provided. The WCCHS cohort (n = 303) constituted the training set, with the PUSZH cohort (n = 85) serving as an external validation set. We evaluated the Apfel score's predictive performance and developed a specialty-specific risk prediction model leveraging its core predictors. AUC differences between models were compared across both datasets.

Ethical approval was obtained from the Biomedical Ethics Committee of PUSZH (Chengdu, China; Approval No. WCHSIRB-D-2025-044-R2). The clinical trial was registered at the International Traditional Medicine Clinical Trial Registry (No. ITMCTR2025001288). All participants provided written informed consent before study enrollment.

Clinical assessment and baseline data collection

Prospectively recorded potential risk factors spanned demographic, anesthetic, and surgical domains: demographic factors included sex, a history of motion sickness(MS)/ PONV, smoking status, age, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status, family history of motion sickness, and State-Trait Anxiety Inventory (STAI) score; anesthetic factor comprised anesthesia duration, anesthetic technique, and postoperative opioids; surgical factors encompassed surgical approach, procedure duration, preoperative fasting time, intraoperative fluid administration per kg, intraoperative blood loss

$$(\text{blood loss(ml)} = \frac{\text{Total weight of blood} - \text{soaked swabs and drapes(g)} - \text{Total dry weight of swabs and drapes(g)}}{\text{Blood density(where 1g/ml is the approximate density of blood)}}$$ and estimated blood loss (ml) = total volume in suction canister (ml) - volume of irrigation fluids used (ml)), postoperative interincisal opening, and timing of prophylactic antiemetics. Additionally, postoperative pain intensity (assessed within 36 h) was recorded to examine its association with PONV.

Patients fasted for 6–8 h and abstained from fluids for 2–4 h before surgery. Upon arrival in the operating room, standard monitoring—including electrocardiography, noninvasive blood pressure, and pulse oximetry—was initiated, and a peripheral intravenous line was established. An experienced anesthesiologist administered a standardized balanced intravenous–inhalational anesthesia regimen. Anesthesia induction consisted of intravenous dexamethasone (5–10 mg), propofol (1.5 mg/kg), sufentanil (0.3–0.4 μg/kg), cisatracurium besylate (0.15 mg/kg), and remimazolam (0.25–0.3 mg/kg). After successful induction, nasotracheal intubation was performed. To minimize airway irritation, lidocaine gel was applied to the distal tip and cuff of the endotracheal tube prior to intubation. Anesthesia was maintained with sevoflurane at 1–1.3 MAC. Remifentanil (0.1–0.2 μg/kg/min) was infused intravenously as required. Dexamethasone was administered at induction, and tropisetron (5 mg) was given intravenously approximately 30 min before the conclusion of surgery. For patients who received postoperative opioid-based patient-controlled intravenous analgesia (PCIA), tropisetron (10 mg) was added to the pump reservoir for continuous infusion. All medication dosages were titrated intraoperatively according to the patient's body weight, age, and physiological parameters.

Patients' anxiety levels were assessed using the State–Trait Anxiety Inventory (STAI). The instrument was administered by uniformly trained researchers during the preoperative evaluation. Before data collection, all researchers underwent standardized training delivered by a psychologist in accordance with the official STAI administration guidelines. This training ensured that researchers provided neutral, standardized instructions to all participants. A quiet, distraction-free environment was provided for participants to complete the questionnaire. During questionnaire administration, researchers offered only literal clarifications for ambiguous items and refrained from providing suggestive or interpretive guidance.

Both investigators administering questionnaires received standardized training. Pretesting and dual verification ensured questionnaire validity and comprehensibility before formal deployment. Electronic questionnaires were administered preoperatively, preceded by informed consent documentation outlining study objectives, methodology, and time requirements; participation commenced only after consent was obtained from patients/families. Investigators instructed participants on self-administering questionnaires and scales independently. For participants with literacy or visual impairments (e.g., presbyopia), investigators verbally explained items and assisted with completion. Demographic factors were captured via questionnaires and medical records preoperatively. Patients were trained to self-report outcomes using investigator-developed PONV/pain assessment forms, later cross-verified against nursing documentation. Anesthetic/surgical variables were extracted from operative and anesthesia records. PONV was defined as nausea, retching, or vomiting within 36 h postoperatively. Retching/vomiting constituted postoperative vomiting (POV); postoperative nausea(PON) severity was assessed via the Nausea Visual Analog Scale (NVAS). During 36 h follow-up (stratified: 0–2 h, 2–6 h, 6–12 h, 12–24 h, 24–36 h), POV frequency and NVAS scores were recorded at each interval. Dual-entry verification with cross-checking in Excel ensured data accuracy.

Primary and secondary outcomes

The primary outcome was the incidence of PONV within 36 h after orthognathic and TMJ surgery. Secondary outcomes included the identification of risk factors associated with PONV in this surgical cohort.

Data analysis

Continuous variables are expressed as medians (interquartile ranges). Categorical variables are expressed as frequencies and proportions. Kruskal-Wallis test, chi-square test, or Fisher's exact test was used for comparison.

Variable selection was performed using Least Absolute Shrinkage and Selection Operator (LASSO) regression, and a multivariate logistic regression model was subsequently constructed with the selected predictors to evaluate their independent association with PONV. LASSO was chosen for its ability to perform variable selection and regularization, with the lambda parameter set to the value that produces the most regularized model with the minimum error.

Model performance was evaluated based on discriminative capacity and calibration metrics. The bootstrap method was used to determine the statistical significance of the differences in AUCs among these indices. Additional details on model performance and validation are provided in the supplementary materials. Given the low proportion of missing data (< 5%), a complete-case analysis was performed by excluding observations with missing values. All statistical significance was determined at $P < 0.05$. Odds Ratio (OR) and their corresponding 95% confidence intervals (CIs) were calculated. Analyses were performed using R 4.3.2, with the rms package (Version 6.7.1) for regression modeling. The reporting of this study adheres to STROBE and TRIPOD recommendations.

Results

Patients characteristics

This study enrolled 388 patients: 221 (56.96%) in the orthognathic surgery group(Le Fort-1/mandibular sagittal osteotomies) and 167 (43.04%) in the TMJ surgery group(Open Temporomandibular Joint Disc Repositioning and Anchorage). The median age was 24 years (IQR: 20–29), with 92.78% (360/388) of patients aged ≤ 44 years. Only 7.47% (29/388) had a smoking history (Table 1). Females comprised 75.77% (294/388) of the cohort, and males 24.23% (94/388). PONV occurred in 62.24% (183/294) of female patients, a rate significantly higher than in males ($P < 0.05$). The highest PONV incidence was observed among females undergoing orthognathic surgery

Variable		Total	Train set	Validate set
Sex, n(%)	Male	94 (24.23%)	72 (23.76%)	22 (25.88%)
	Female	294 (75.77%)	231 (76.24%)	63 (74.12%)
History of MSorPONV, n(%)	No	144 (37.11%)	112 (36.96%)	32 (37.65%)
	Yes	244 (62.89%)	191 (63.04%)	53 (62.35%)
Smoke, n(%)	No	359 (92.53%)	280 (92.41%)	79 (92.94%)
	Yes	29 (7.47%)	23 (7.59%)	6 (7.06%)
Postoperative opioids, n(%)	No	233 (60.05%)	185 (61.06%)	48 (56.47%)
	Yes	155 (39.95%)	118 (38.94%)	37 (43.53%)
Age, n(%)	01∼4 years	18 (4.64%)	16 (5.28%)	2 (2.35%)
	15∼24 years	183 (47.16%)	149 (49.17%)	34 (40.00%)
	25∼44 years	159 (40.98%)	110 (36.30%)	49 (57.65%)
	45∼100 years	28 (7.22%)	28 (9.24%)	0 (0.00%)
BMI, n(%)	<18.5 kg/m²	91 (23.45%)	69 (22.77%)	22 (25.88%)
	18.5∼23 kg/m²	220 (56.70%)	171 (56.44%)	49 (57.65%)
	24∼27 kg/m²	65 (16.75%)	54 (17.82%)	11 (12.94%)
	≥28 kg/m²	12 (3.09%)	9 (2.97%)	3 (3.53%)
ASA, n(%)	Ⅰ	60 (15.46%)	0 (0.00%)	60 (70.59%)
	Ⅱ	321 (82.73%)	298 (98.35%)	23 (27.06%)
	Ⅲ	7 (1.80%)	5 (1.65%)	2 (2.35%)
MS, n(%)	No	166 (42.78%)	124 (40.92%)	42 (49.41%)
	Yes	222 (57.22%)	179 (59.08%)	43 (50.59%)
Family history of MS, n(%)	No	227 (58.51%)	164 (54.13%)	63 (74.12%)
	Yes	161 (41.49%)	139 (45.87%)	22 (25.88%)
History of PONV, n(%)	No	331 (85.31%)	279 (92.08%)	52 (61.18%)
	Yes	57 (14.69%)	24 (7.92%)	33 (38.82%)
SAI, (median [IQR])		49 (45.75,52)	48 (45,51)	52 (49,55)
TAI, (median [IQR])		48 (44,51)	46 (43,50)	52 (49,55)
STAI, (median [IQR])		97 (90,103)	95 (89,100)	104 (97,109)
Anesthetic time, (median [IQR])		3.6 (2.5,5)	3.2 (2.25,4.7)	6 (5,6)
Preoperative fasting, (median [IQR])		13 (12,16)	13 (12,16)	13 (12,16)
Preoperative fluid fasting, (median [IQR])		10.5 (8,13)	10 (8,12)	12 (7,13)
Type of surgery, n(%)	Orthognathic surgery	221 (56.96%)	143 (47.19%)	78 (91.76%)
	TMJ surgery	167 (43.04%)	160 (52.81%)	7 (8.24%)
Surgical Approach, n(%)	Uni-Jaw Surgery	51 (13.14%)	42 (13.86%)	9 (10.59%)
	Bi-jaw Surgery	170 (43.81%)	101 (33.33%)	69 (81.18%)
	Unilateral TMJ	102 (26.29%)	97 (32.01%)	5 (5.88%)
	Bilateral TMJ	65 (16.75%)	63 (20.79%)	2 (2.35%)
Operation timeH, n(%)	0∼3h	210 (54.12%)	187 (61.72%)	23 (27.06%)
	3∼6h	174 (44.85%)	112 (36.96%)	62 (72.94%)
	≥6 h	4 (1.03%)	4 (1.32%)	0 (0.00%)
The intraoperative IV fluid, n(%)	< 25 ml/kg	231 (59.54%)	205 (67.66%)	26 (30.59%)
	≥25 ml/kg	157 (40.46%)	98 (32.34%)	59 (69.41%)
Intraoperative blood loss, (median [IQR])		60 (20,200)	50 (17.5,150)	150 (100,200)
POV, n(%)	Yes	166 (42.78%)	131 (43.23%)	35 (41.18%)
PON, n(%)	Yes	221 (56.96%)	161 (53.14%)	60 (70.59%)
PONV, n(%)	Yes	226 (58.25%)	166 (54.79%)	60 (70.59%)

Table 1. The distribution of patient demographic characteristics and factors related to anesthesia and surgery. STAI: State-Trait Anxiety Inventory; SAI: State-Anxiety Inventory; TAI: Trait-Anxiety Inventory.

(63.98%) (Table 2). The overall PONV incidence was 58.25%(226/388), comprising POV alone 42.78%(166/388), PON alone 56.96%(221/388), and concurrent POV and PON 41.50%(161/388) (Table 1). All patients with POV also experienced PON. Among patients with PONV,39.95% (155/388) received opioids. PONV, POV, and PON occurred most frequently within the first 6 h postoperatively, peaking at 2–6 h (Fig. 1), followed by 0–2 h, with incidence gradually declining thereafter.

Variables	Univariate analysis		Multivariate analysis	
	OR (95%CI)	*P* value	OR (95%CI)	*P* value
Sex				
Male	Reference		Reference	
Female	2.72 (1.58 ~ 4.76)	< 0.001*	1.99 (1.06–3.75)	0.032*
Smoke				
No	Reference		Reference	
Yes	0.21 (0.07 ~ 0.53)	0.002*	0.29 (0.09–0.84)	0.031*
Postoperative opioids				
No	Reference		Reference	
Yes	1.6 (1.01 ~ 2.58)	0.049*	1.92 (1.15–3.23)	0.014*
Age (year)			–	
0 ~ 14	Reference			
15 ~ 24	1.06 (0.36 ~ 3)	0.91		
25 ~ 44	0.72 (0.24 ~ 2.08)	0.548		
45 ~ 100	1.4 (0.39 ~ 4.96)	0.599		
BMI(kg/m²)			–	
<18.5	Reference			
18.5 ~ 23	1.1 (0.62 ~ 1.92)	0.752		
24 ~ 27	0.82 (0.4 ~ 1.67)	0.576		
≥ 28	0.41 (0.08 ~ 1.68)	0.23		
ASA				
II	Reference		Reference	
III	0.2 (0.01 ~ 1.38)	0.154	0.12 (0.01–1.09)	0.084
History of MS			–	
No	Reference			
Yes	1.24 (0.78 ~ 1.97)	0.356		
Relative MS				
No	Reference		Reference	
Yes	1.45 (0.92 ~ 2.29)	0.113	1.45 (0.89–2.39)	0.138
History of PONV				
No	Reference		Reference	
Yes	2.66 (1.08 ~ 7.5)	0.045*	2.47 (0.93–7.56)	0.087
SAI Score	1 (0.95 ~ 1.04)	0.822	–	
TAI Score	0.97 (0.93 ~ 1.01)	0.186	–	
STAI Score	0.99 (0.97 ~ 1.01)	0.397	–	
Anesthetic time(h)	1 (0.86 ~ 1.17)	1	–	
Preoperative fasting time(h)	1.04 (0.97 ~ 1.11)	0.244	–	
Preoperative fluid fasting time(h)	1.02 (0.96 ~ 1.08)	0.569	–	
Type of surgery			–	
orthognathic surgery	Reference			
TMJ surgery	1.74 (1.11 ~ 2.76)	0.017*		
Surgical Approach				
uni-Jaw Surgery	Reference		Reference	
bi-jaw Surgery	2.67 (1.27 ~ 5.86)	0.012*	2.04 (0.76–5.54)	0.155
unilateral TMJ	2.8 (1.32 ~ 6.19)	0.008*	2.07 (0.93–4.75)	0.080
bilateral TMJ	5.17 (2.26 ~ 12.39)	< 0.001*	4.15 (1.72–10.44)	0.002*
operation time			–	
0 ~ 3h	Reference			
3 ~ 6h	0.87 (0.54 ~ 1.39)	0.559		
≥ 6 h	0.78 (0.09 ~ 6.62)	0.807		
The intraoperative IV fluid				
<25 ml/kg	Reference		Reference	
≥ 25 ml/kg	1.3 (0.8 ~ 2.13)	0.288	1.59 (0.73–3.53)	0.249
Intraoperative blood loss	1 (1 ~ 1)	0.989	–	

Table 2. Logistic regression analysis of PONV risk factors in study patients ($n = 388$). *P < 0.05.

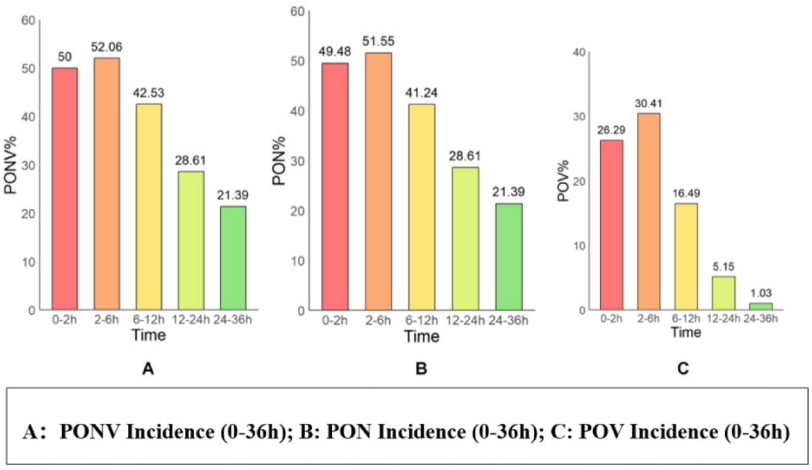

Fig. 1. The Incidence of PONV within 36 h after operation.

Models	AUC for PONV % (95%CI)	*P* value
Training set		
Model 1: Apfel	64.20 (58.11–70.29)	–
Model 2: novel model	72.79 (67.03–78.55)	< 0.001
Validation set		
Model 1: Apfel	59.77 (45.69–73.84)	–
Model 2: novel model	71.07 (59.14–82.99)	0.005

Table 3. Area under the receiver operating characteristic curve (AUC) for PONV in the training and validation set.

Risk factors for PONV

Variables were selected using LASSO regression. Univariate analysis revealed that female gender, non-smoker, postoperative opioids, history of PONV, and TMJ surgery approach (including bilateral approach) were significantly associated with PONV incidence ($P < 0.05$). Multivariable logistic regression analysis identified eight independent predictors retained in the final model: female gender, non-smoker, postoperative opioids, ASA physical status, family history of MS, history of PONV, surgical approach, and intraoperative fluid volume. In the multivariable model, female gender was a significant positive predictor of PONV (odds ratio [OR] = 1.99, 95% confidence interval [CI]: 1.06–3.75; $P = 0.032$). Smokers demonstrated a significantly negative association with PONV compared to non-smokers (OR = 0.29, 95% CI: 0.09–0.84; $P = 0.031$). Postoperative opioids were significantly associated with an increased incidence of PONV (OR = 1.92, 95% CI: 1.15–3.23; $P = 0.014$). Analysis of surgical approach indicated that bilateral TMJ surgery was associated with a significantly higher PONV incidence compared to unilateral TMJ and orthognathic surgery (single or double jaw), with an OR of 4.15 (95% CI: 1.72–10.44; $P = 0.002$) (Table 2).

Notably, certain variables (e.g., surgical type, history of MS) that were significant in univariate analysis were excluded from the multivariable model. This suggests potential collinearity, where their effect may be mediated by other variables. For instance, surgical type was a significant positive predictor in univariate analysis (OR = 1.74, 95% CI: 1.11–2.76; $P = 0.017$) but lost statistical significance in the multivariable model. In summary, logistic regression effectively identified independent predictors—including female gender, non-smoker, postoperative opioids, and surgical approach—providing a statistical foundation for PONV prevention and management in orthognathic and TMJ surgery patients (Table 2).

Comparison of risk prediction models for PONV

A PONV risk prediction model was developed using LASSO-logistic regression for patients undergoing orthognathic and TMJ surgery. Internal validation via bootstrap resampling (1000 replicates) yielded a C-statistic of 0.714, with a calibration intercept of -0.005 and slope of 1.023 (Table S1). External validation demonstrated a C-statistic of 0.71 (95% CI: 0.58 to 0.81), a calibration intercept of 0.15 (95% CI: -0.31 to 0.60), and a calibration slope of 1.00 (95% CI: 0.31 to 1.69) (Fig. S1). In contrast, the Apfel score demonstrated an AUC of 0.62 (95% CI: 0.56 to 0.68) for predicting PONV in this cohort (Fig. S2). Its discriminatory performance was significantly lower than that of the novel risk prediction model in both the training ($P < 0.001$) and validation ($P = 0.005$) sets (Table 3).

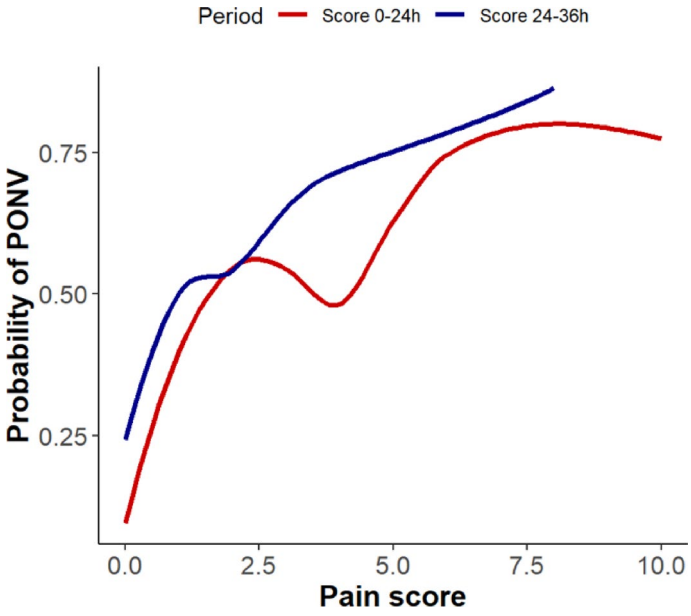

Fig. 2. The association between postoperative pain scores and PONV.

The association between postoperative pain and PONV

We assessed the association between pain scores and the incidence of PONV. A positive association was observed between higher pain scores and an increased incidence of PONV. The risk probability of PONV increased significantly at higher pain scores (> 2.5). At lower pain scores (0–2.5), the risk probability was low for both periods and increased gradually. For pain scores between 2.5 and 5.0, the PONV probability was slightly higher in the 24–36 h postoperative period than in the 0–24 h period. At pain scores > 5.0, the risk continued to rise for the 24–36 h period, while it plateaued for the 0–24 h period after reaching a certain threshold (Fig. 2).

Discussion

This study found a high incidence of PONV (58.25%) following orthognathic and TMJ surgery, a rate significantly higher than that reported for other surgical types[17], and consistent with previous literature[3]. Notably, the risk of PONV was marginally higher in patients undergoing TMJ procedures compared to those receiving orthognathic surgery (Table 2), a distinction not sufficiently addressed in previous studies. TMJ surgery is principally indicated for temporomandibular disorders (TMD), which have a multifactorial etiology that includes joint trauma, intra-articular pathology, and systemic disease, with psychosocial factors (e.g., anxiety) also recognized as important contributors[18–20]. Furthermore, the incidence of TMD is approximately twice as high in women as in men, particularly between ages 35 and 44[21], which aligns with our finding that 92.78% of the cohort was ≤ 44 years old. Female gender, an established independent predictor of PONV, also demonstrated strong predictive utility within our risk prediction model. The higher proportion of women in clinical TMD populations may be attributed to greater health awareness and higher susceptibility to anxiety[22], potentially leading to increased symptom reporting and diagnosis rates. Therefore, patients undergoing TMJ surgery constitute a population with a predominance of female individuals, warranting particular consideration in the management of PONV.

Smoking was identified as an independent protective factor against PONV (OR = 0.29, 95%CI: 0.09–0.84; $P = 0.031$). Established risk models by Apfel[23] and Sinclair[24]both incorporate a non-smoker, which is a well-documented predictor of higher PONV risk[25]. Regarding the underlying mechanism, Chimbira et al.[26]proposed that polycyclic aromatic hydrocarbons (PAHs) in tobacco may induce hepatic cytochrome P450 enzyme activity, thereby accelerating the metabolic clearance of emetogenic substances and reducing PONV risk. Notably, our cohort of orthognathic and TMJ surgery patients comprised a high proportion of women (75.77%)—a demographic with a historically lower smoking prevalence[27]. This confluence of demographic risk factors likely contributes to the elevated PONV incidence observed in this study.

This study confirmed postoperative opioid use as an independent risk factor for PONV in orthognathic and TMJ surgery patients (OR = 1.92, 95% CI: 1.15–3.23; $P = 0.014$), a finding consistent with the report by Rashad et al.[28]. The actual PONV risk associated with opioid exposure in this specific cohort may exceed the value predicted by the model. This elevated risk is likely mechanistically driven by the extensive surgical trauma—involving bone, joints, muscles, and neural tissue—particularly in bimaxillary or bilateral joint procedures. This trauma precipitates more severe and prolonged postoperative pain[29,30], consequently necessitating greater opioid analgesic requirements. This thereby elevates the risk of PONV in this population. Despite adherence to Enhanced Recovery After Surgery (ERAS) protocols employing multimodal prophylaxis (including combination antiemetic therapy)[17,31]and individualized dosing, it is often difficult to completely avoid opioid use in the management of moderate-to-severe postoperative pain in this population.

Multivariable analysis identified open bilateral TMJ Disc Repositioning and Anchorage surgery as the most potent independent risk factor for PONV (OR = 4.15, 95%CI: 1.72–10.44; $P = 0.002$), with a stronger predictive effect than unilateral TMJ Disc Repositioning and Anchorage or orthognathic procedures. We hypothesize that this finding is fundamentally associated with the anatomical invasiveness and extensive nature of the procedure. The bilateral approach inherently doubles both the surgical trauma and the operative field, resulting in substantially longer operative duration and greater tissue exposure compared with unilateral surgery. Moreover, the open technique requires broad tissue dissection and sustained retraction to achieve adequate exposure of the TMJ region, which is situated adjacent to dense plexuses of trigeminal sensory branches and the auricular branch of the vagus nerve. Consequently, bilateral open surgery imposes prolonged and diffuse mechanical stimulation—including traction, compression, and postoperative edema—on these vulnerable neural structures. This can activate the vomiting center via the enhanced release of neuropeptides (e.g., substance P) and neurotransmitters (e.g., 5-HT3)[32–34]. Although complete avoidance of neural traction or stimulation remains challenging in open TMJ surgery, the development of minimally invasive arthroscopic techniques has significantly reduced the risk of iatrogenic nerve injury[35].

In contrast to the classic Apfel score, combining a history of MS and a history of PONV into a single composite variable for risk prediction analysis did not yield a statistically significant association in this study. However, when analyzed as separate independent variables, a history of PONV, but not motion sickness, was significantly associated with an increased risk of PONV. This suggests that a history of PONV and a history of MS may have divergent predictive values for PONV risk. Combining these factors may obscure their distinct clinical impacts and underlying mechanisms. Separate assessment provides clinicians with more specific, targeted information for granular risk assessment and the development of tailored preventive strategies.

Patients reporting moderate-to-severe pain (score ≥ 5 on a 0–10 scale) beyond 24 h after operation should be identified as high-risk for PONV, based on its established association with pain intensity. Effective postoperative analgesia not only mitigates pain but also significantly reduces the risk of PONV[36], an effect particularly crucial in the later postoperative period. Patients undergoing orthognathic and TMJ surgery exhibit a distinct pain trajectory. Early postoperative pain (< 24 h) is often effectively masked by residual anesthetic effects and patient-controlled analgesia (PCA). However, in the subsequent 24-36-hour period, the confluence of waning analgesia and antiemetic prophylaxis[37], plus a surgery-induced inflammatory cascade (e.g., peak serum levels of pro-inflammatory cytokines like IL-6)[38], may heighten emetogenic susceptibility and synergistically increase PONV risk.

In summary, despite the efficacy of standardized antiemetic protocols within a multidisciplinary approach that have effectively reduced perioperative PONV incidence, patients undergoing orthognathic and TMJ surgery remain at significantly higher risk compared to general surgery populations, underscoring the need for optimized preventive strategies. Furthermore, while existing studies suggest that traditional Chinese acupoint stimulation may effectively prevent PONV in some surgical contexts, its efficacy specifically in orthognathic and TMJ surgery lacks validation from randomized controlled trials (RCTs). Therefore, future research should include prospective RCTs to evaluate the prophylactic efficacy of traditional Chinese medicine interventions for PONV in this cohort and to establish a precision prediction-prevention system based on large-scale, multicenter data.

Limitations and strengths

Because the timing of postoperative pain overlaps with the occurrence of PONV, pain scores could not be included as a predictive risk factor. Consequently, our analysis focused solely on examining the association between pain intensity and the risk of developing PONV. Despite this limitation, our findings suggest a potential relationship between pain and PONV. Future studies should extend the duration of postoperative monitoring and follow-up to investigate the immediate impact of dynamic pain changes on PONV. This would help refine risk prediction models and enhance the precision of clinical interventions. Current routine antiemetic protocols, which are primarily concentrated within the first 24 h post-surgery, may leave a gap in protection for these patients. There is a pressing need for prospective research to determine whether extending prophylactic antiemetic therapy can further reduce the incidence of late-onset PONV and optimize the synergistic management of analgesia and nausea prevention. To our knowledge, this is the only multicenter, prospective cohort study to date examining PONV risk specifically in patients undergoing orthognathic and TMJ surgery. By meticulously recording patient symptoms and medication use, we generated robust empirical data that strengthens the validity of our conclusions. Furthermore, the multicenter design was instrumental in minimizing selection bias and enhancing the generalizability of the results.

Conclusions

Patients undergoing orthognathic and TMJ surgery exhibit a high incidence of PONV. We identified female sex, non-smoker, postoperative opioids, history of PONV, and bilateral TMJ surgery as independent predictors for PONV in this cohort. While a strong association was observed between pain and PONV risk, the persistence of this relationship warrants further investigation. A novel prediction model incorporating these specific predictors demonstrated superior discriminative performance compared to the Apfel score. These findings should inform tailored prophylactic strategies to mitigate PONV risk in this surgical population.

Data availability

The datasets generated and/or analysed during the current study are not publicly available due to privacy restrictions related to human participant data but are available from the corresponding author on reasonable request.

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Author contributions
Liyan Mao and Xiaoqin Bi designed the study.Liyan Mao and Yajun Li conducted pre-operative evaluations and were responsible for the collection and electronic entry of follow-up data for patients treated at West China Hospital of Stomatology, Sichuan University. Weijun Liu performed the corresponding tasks—pre-operative assessment, follow-up data collection, and data entry—for patients managed at Peking University Shenzhen Hospital. Yunyu Zhou, Jingya Yu, and Xuemei Yang organized and checked the data. Liyan Mao, Min Liu, and Chongyang Zhao performed all statistical analyses. Liyan Mao wrote the final manuscript. Wenbin Huang, Chongyang, and Grace Paka Lubamba revised the manuscript. All authors contributed to the article and approved the submitted version.

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Declarations

Competing interests
The authors declare no competing interests.

Clinical relevance
Patients undergoing orthognathic and TMJ surgery exhibit a high incidence of PONV. Incorporating specific predictors into the Apfel score enhances PONV prediction accuracy in this population, thereby informing evidence-based prophylaxis.

Contributions
Liyan Mao and Xiaoqin Bi designed the study.Liyan Mao and Yajun Li conducted pre-operative evaluations and were responsible for the collection and electronic entry of follow-up data for patients treated at West China Hospital of Stomatology, Sichuan University. Weijun Liu performed the corresponding tasks—pre-operative assessment, follow-up data collection, and data entry—for patients managed at Peking University Shenzhen Hospital. Yunyu Zhou, Jingya Yu, and Xuemei Yang organized and checked the data. Liyan Mao, Min Liu, and Chongyang Zhao performed all statistical analyses. Liyan Mao wrote the final manuscript. Wenbin Huang, Chongyang, and Grace Paka Lubamba revised the manuscript. All authors contributed to the article and approved the submitted version.

Ethical approval
All procedures conducted in this research, which included human participants, were in accordance with the Helsinki Declaration, 1964. Approval for the trial was granted by the Institutional Ethics Committee (WCHSIRB-D-2025-044-R2).

Additional information
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