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ORIGINAL ARTICLE

Risk stratification against inferior alveolar nerve injury after lower third molar extraction by scoring on cone-beam computed tomography image

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Abstract

The study aimed to stratify the risk of inferior alveolar nerve injury (IANI) after lower third molar (LM3) surgery with a scoring system using identified predictive factors based on cone-beam computed tomography (CBCT) images. In a case–control study, the primary outcome was IANI occurrence. The control group included randomly selected patients without IANI. Predictor variables included patient demographics, surgical situations, Pell–Gregory classification, and inferior alveolar canal (IAC)-associated factors on CBCT. Study variables were analyzed using logistic regression models. Risk stratification was assessed by a scoring system that was constructed using independent predictors. The 858 patients who underwent LM3 surgery (1177 teeth) after CBCT scan were divided into case (25 patients, 2.9%, 27 teeth) and control (235 patients, 300 teeth) groups. In the multivariate model, lingual/inter-radicular position of IAC [odds ratio (OR) 7.21; $P<0.001$; assigned score, 2], multiple roots closed to the IAC with cortical perforation (OR 3.72; $P=0.015$; 1), and age > 30 years (OR 4.99; $P=0.008$; 2) were associated with an increased IANI-risk. The IANI-risk scoring system could be stratified into low- and high-risk groups at a cutoff score of 3 (sensitivity, 68.0%; specificity, 90.6%; positive predictive value, 17.8%; positive likelihood ratio, 7.23). In conclusion, the high-risk group of IANI after LM3 surgery corresponded to individuals with multiple factors: lingual/inter-radicular IAC position to LM3, multiple roots with perforated IAC, and increased age (> 30 years). Raising awareness of the higher probability for IANI is needed for patients with multiple aforementioned factors.

Keywords Cone-beam computed tomography · Tooth extraction · Third molar surgery · Scoring system · Inferior alveolar canal

Introduction

Extraction of the lower third molars (LM3s) can provoke troublesome symptoms postoperatively, including pain, swelling, edema, and trismus. Although uncommon, inferior alveolar nerve injury (IANI) can negatively impact patients' quality of life [1, 2]. To reduce its risk, preoperative assessment is crucial [3], particularly the anatomic relationships between LM3 and the inferior alveolar canal (IAC) using radiographic modalities [4, 5].

On standard panoramic tomography, Rood and Shehab [6] presented seven imaging signs related to IANI, including interruption of the white line, narrowing, and diversion of the IAC; darkening/narrowing of the roots; and dark/bifid and deflected roots. In cases suggestive of close proximity between the LM3 root and IAC, a computed tomography (CT) scan is also recommended [7, 8]. The CT findings of the IAC to LM3 roots, such as the lingual position to LM3, deformed shape in coronal sections, and cortical perforation, have been associated with IANI occurrence [7, 9–11]. Cone-beam CT (CBCT) has been used frequently to estimate IANI-risk due to high spatial resolution and low radiation dosage [2, 4, 12, 13], although this modality should be applied not routinely but when the surgeon has strong clinical reservations after use of the conventional imaging [14].

Owing to low incidence [4], few studies have reported its reliable predictors on CBCT imaging using multivariate analysis [15], and stratification of IANI risk against its

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scoring system remains unestablished [16]. Based on the features of the relationship between LM3 roots and IAC on CBCT imaging, we explored predictable factors affecting the probability of IANI after LM3 surgery, using multivariate logistic regression methods with covariates, such as patient demographics. Furthermore, we assessed diagnostic parameters of a scoring system that might help to preoperatively stratify the IANI-risk.

Materials and methods

Study design and sample

This retrospective, case–control study was approved by the internal review boards of our institution and was conducted in accordance with the Declaration of Helsinki. Data on patients who underwent LM3 extraction with preoperative CBCT evaluation were acquired from the electronic charts from October 2010 to April 2018.

Patients with the following findings on panoramic radiography were candidates for additional CBCT before LM3 extraction: a close relationship between IAC and LM3 [6], abnormal root shape features, or radiographic changes in the surrounding area suggestive of osteomyelitis, cyst, or tumors. CBCT images were taken using the Alphard-3030 (Alphard VEGA®; Asahi Roentgen Ind. Co., Ltd, Kyoto, Japan) with a slice thickness of 0.65 mm (scanning time, 17 s; tube voltage, 80 kV; tube current, 2–15 mA; voxel size, 0.2 mm; the field of view size, 102 mm × 102 mm). LM3 extraction was performed by oral and maxillofacial surgery staff or under their instruction in principle if surgeons had < 5 years of experience.

IANI cases were patients with postoperative neurosensory weakness of the lower lip and mental area. The control group included randomly selected patients without any subsequent IANI [17] (approximately 1:9 ratio of cases-to-controls [18]). Exclusion criteria were patients < 16 years old, LM3s were associated with surrounding cyst or tumors, and whose postoperative clinical follow-up data at 1 week were unavailable. Regarding patients with bilateral surgeries in a case-based analysis, either side was sampled randomly when patients had the same outcome (i.e., bilaterally injured or intact sensory function). In patients with dual outcomes (i.e., one side injured and the other with intact sensory function), IANI side was sampled.

Study variables

Patient-related variables included age and sex. The age was converted to a categorical variable with a cutoff value of 30 years according to previous studies [9, 10]. Surgery-related variables included anesthesia (general/local, or intravenous sedation), surgeon experience (≥ 5 or < 5 years), and extraction side. Anatomic variables included impaction levels of LM3 recorded from panoramic radiographs in accordance with Pell-Gregory classification. Class I/II/III indicated the horizontal position of LM3 relative to the anterior border of the ramus (level of the posterior impaction). Position A/B/C indicated the vertical relationship to the mandibular occlusal plane (the level of the inferior impaction).

Radiographic variables on the coronal sections of CBCT included the buccolingual position of the IAC to LM3, categorized as the buccal, inferior lingual, or inter-radicular position (Fig. 1) [7]. The IAC shape at the section closest to the roots was categorized as round/oval, teardrop,

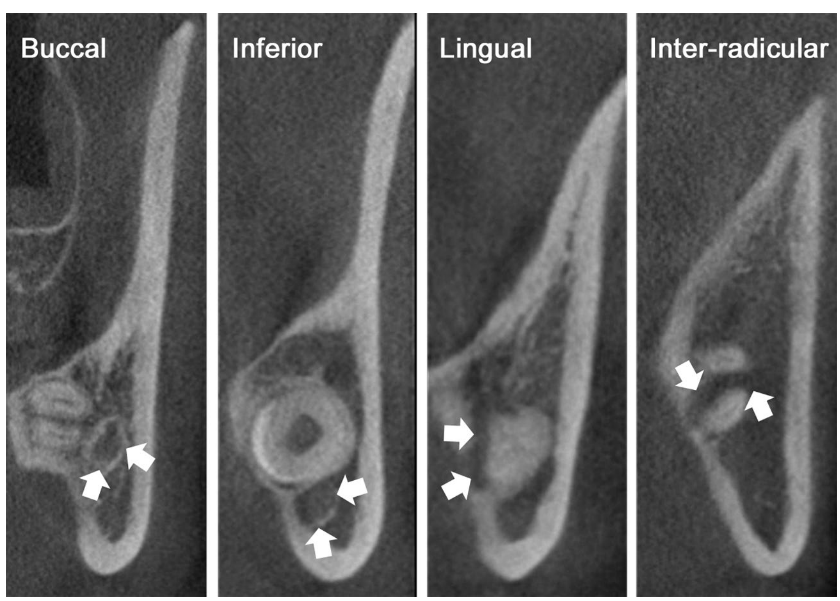

Fig. 1 Position of the inferior alveolar canal (IAC) to the third molar roots on cone-beam computed tomography. The IAC position on the coronal section (arrows) was categorized into the buccal side to lower third molars, inferior side, lingual side, and inter-radicular position [7]

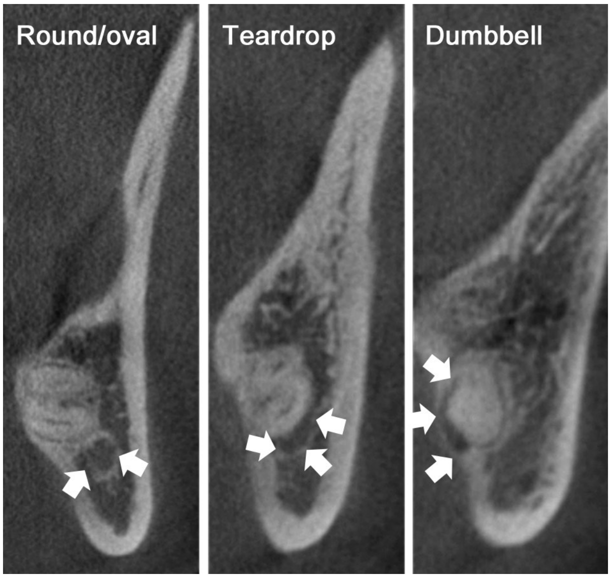

Fig. 2 Shape of the inferior alveolar canal (IAC) on cone-beam computed tomography. The IAC shape (arrows) was categorized as round/oval, teardrop, and dumbbell on the coronal section in the closest proximity between the lower third molars and IAC [9]

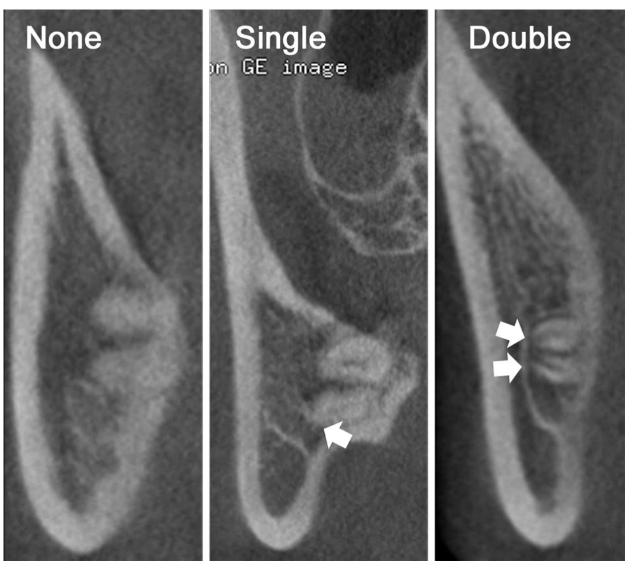

Fig. 3 Contact between the roots and perforated inferior alveolar canal (IAC). The number of roots contacting the perforated IAC is counted as none, single, and double

or dumbbell (Fig. 2) [9]. Regarding IAC cortication with adjacent LM3 roots, the number of roots close to the IAC with cortical perforation was recorded (Fig. 3). The images were evaluated independently by a graduate student and a specialist. The inter-examiner agreements of the IAC position and shape and the number of roots with perforated IAC were closely aligned (weighted $\kappa = 0.752$, 0.772, and 0.810, respectively). Inconsistent data were retrieved again by the specialist.

Outcome variable was the presence (study group) or absence (control group) of IANI at 1 week (days 6–8) after LM3 extraction. The patients were questioned regarding the sensitivity of the lower lip and mental areas. Sensory disturbances were detected using the pin-prick, light touch, or Semmes–Weinstein test. In the study group, the outcome was also postoperatively assessed by follow-up at 1, 3, and 6 months. Neurosensory disturbance detected at > 6 months postoperatively was considered as permanent.

Statistical analyses

Categorical variables were presented as frequency (percentage). Fisher's exact test (cell value < 5) or Pearson's χ^2 test was used to capture possible associations between IANI and those variables. The Cochran–Armitage test was conducted as χ^2 test for trend in proportions. For logistic regression analysis, IAC shapes of round/oval and teardrop were merged, the four components of the IAC position were integrated into the buccal/inferior and lingual/inter-radicular position, and the number of roots with perforated IAC was coded as non/single or multiple. Univariate models were applied to obtain the odds ratios (ORs) and 95% confidence intervals (CIs) of IANI occurring and to assess the study variables' effects. Subsequently, the variables with a *P* value of < 0.1 in those models were simultaneously subjected to multivariate models to identify the predictive factors for IANI. Backward stepwise algorithms were definitively used, with the exclusion of those variables failing to fit the model significantly. Additional logistic regression analyses allowing duplication of cases with bilateral teeth extraction were performed as a sensitivity analysis [19].

Statistical significance was considered at $P < 0.05$. Statistical analyzes were conducted using SPSS, version 25.0 (SPSS, Chicago, IL, USA) and R 3.4.1 software program (R Foundation for Statistical Computing, Vienna, Austria).

Risk scoring

To construct the IANI-risk scoring system (IANI-RSS), regression coefficients of significant variables in the stepwise multivariate logistic model were converted into adjusted integers [20]. The OR 95% CI of IANI occurrence in each risk score of IANI-RSS, and area under receiver operating characteristic (ROC) curve were examined. Furthermore, diagnostic values of IANI-RSS were calculated at every cutoff point, including sensitivity, specificity, positive (PPV) and negative (NPV) predictive values, positive (PLR) and negative (NLR) likelihood ratios, and Youden index (sensitivity + specificity − 1).

Results

Of 858 patients (1177 teeth) who underwent LM3 extraction after CBCT imaging, 25 (7 men, 18 women; median age, 39 years; range 23–55) with 27 teeth had IANI with a patient-based incidence of 2.9%. The control group included 235 randomly selected patients (103 men, 132 women; median age, 31 years; range, 16–82; 273 teeth).

Relationship between each variable and IANI

Bivariate analysis (Table 1) included patient- and tooth-based assessments performed on demographics and other variables, respectively. Statistical comparison between the study and control groups indicated that patient age (> 30 years; $P = 0.005$), anatomical classification of "Class" ($P = 0.046$), and all IAC feature components on CBCT ($P < 0.001$) were associated with an increased IANI-risk. No statistically significant difference was detected among the other variables examined.

Identification of predictive factors for IANI

Univariate logistic regression analyses (Table 2) showed that increased age (> 30 years) (OR 4.54; 95% CI 1.51–13.60; $P = 0.007$), anatomic Class III LM3 classification (OR 2.44; 95% CI 1.01–5.89 $P = 0.047$), lingual/inter-radicular IAC position (OR 10.70; 95% CI 4.38–26.10; $P < 0.001$), dumbbell-shaped IAC features on CBCT (OR 5.17; 95% CI 2.15–12.40; $P < 0.001$), and multiple roots with perforated IAC (OR 6.05; 95% CI 2.50–14.70; $P < 0.001$) were associated with IANI probability. The anatomic classification of Position C was identified as a non-significant variable with a p-value of 0.082 ($P < 0.1$).

Among those variables, simultaneous and stepwise multivariate analyses identified similar significant predictors: these were increased age [OR 4.19; 95% CI 1.24–14.21; $P = 0.021$ (simultaneous); and OR 4.99; 95% CI 1.53–16.30; $P = 0.008$ (stepwise)], IAC position (OR 6.13; 95% CI 2.21–16.98; $P < 0.001$; and OR 7.21; 95% CI 2.67–19.40; $P < 0.001$), and multiple roots (OR 3.61; 95% CI 1.05–12.38; $P = 0.041$; and OR 3.72; 95% CI 1.29–10.70; $P = 0.015$). A tooth-based model as a sensitivity analysis also identified the same independent factors.

Risk scoring and stratification

A scoring system was constructed to evaluate and stratify IANI-risk. The model was shown in Table 3 as the sum of those adjusted integers. The area under the ROC curve of the IANI-RSS was 0.83 (95% CI 0.75–0.92). Regarding the association between IANI occurrence and its risk score (Table 4), marked gaps of their ORs were seen between scores 2 and 3 in the model. Diagnostic parameters, such as sensitivity, specificity, PPV, or NPV, were calculated at every cutoff point of the IANI-RSS (Table 5). Escalating a cutoff score led to increased PPVs from 4.3 to 18.7%, and slightly decreased NPVs from 99.7 to 97.6%, with adjustment based on the overall incidence of IANI (2.9%, 25/858 patients). Score of 3 (maximum of Youden index) was assigned as a cutoff point for categorization into low- and high-risk groups. The sensitivity, specificity, PPV, NPV, PLR, and NLR were 68.0%, 90.6%, 17.8%, 99.0%, 7.23, and 0.35, respectively. In this system, patients with multiple factors of three identified predictors would have score of 3 or more, corresponding to the high-risk group.

Clinical course of cases with IANI

Of 25 patients with IANI, 11 (44%) recovered within 1 month postoperatively, and 3 (12%) and 4 (16%) within 3, and 6 months, respectively. Only one (4%) had persistent IANI at 1 year postoperatively, and this was considered permanent. No patient with IANI underwent satellite ganglion block or microsurgery for nerve reconstruction. The remaining six patients (24%) were lost to follow-up within 6 months postoperatively.

Discussion

The lingual/inter-radicular IAC position to LM3 position, multiple roots contacted with perforated IAC, and increased age significantly enhanced the probability of LM3 surgery-associated IANI. Of these, the second is a newly identified predictor. Scoring of these factors allowed the dual stratification of IANI-risk. The overall incidence of IANI accounted for 2.9% (25/858 patients with a possibly increased risk of IANI, as diagnosed on panoramic radiographs, followed by CBCT scan). This complication rate was acceptable (previously reported range ≤ 8.4%) [1, 8, 21].

Regardless of disadvantages compared to panoramic radiography, including higher cost and higher radiation exposure [4], CT would be superior regarding accurate and detailed visualization of local anatomy, contributing to preoperative planning [7, 22–24]. Some investigators [25–27] advocated that preoperative CT failed to reduce IANI occurrence after LM3 surgery; nonetheless, Korkmaz et al. [8] reported feasibility of CT imaging for preventing temporary IANI. CT would contribute to obtaining informed consent from patients with high risk of IANI based on their accurate recognition [11, 22].

We analyzed three components of IAC features on CBCT imaging: IAC position and shape, and number of roots with

Table 1 A bivariate analysis of variables grouped by patients with and without inferior alveolar nerve injury

Variable	Control Absence of IANI $n = 235$	Case Presence of IANI $n = 25$	*P* value
Patient-based analysis, $n = 260$			
Age			
≤ 30 years	109 (46.4)	4 (16.0)	0.005
> 30 years	126 (53.6)	21 (84.0)	
Sex			
Male	103 (43.8)	7 (28.0)	0.142
Female	132 (56.2)	18 (72.0)	
	$n = 300$	$n = 27$	
Tooth-based analysis, $n = 327$			
Situations of surgery			
Anesthesia			
General	71 (23.7)	8 (29.6)	0.529
IVS	9 (3.0)	1 (3.7)	
Local	220 (73.3)	18 (66.7)	
Operator			
Resident/graduate fellow	70 (23.3)	6 (22.2)	1.000
Staff	230 (76.7)	21 (77.8)	
Extraction side			
Left	148 (49.3)	16 (59.3)	0.422
Right	152 (50.7)	11 (40.7)	
Anatomical classification of 3rd molars			
Class[a]			
I	42 (14.0)	1 (3.7)	0.046
II	197 (65.7)	17 (63.0)	
III	61 (20.3)	9 (33.3)	
Position[a]			
A	122 (40.7)	7 (25.9)	0.055
B	144 (48.0)	14 (51.9)	
C	34 (11.3)	6 (22.2)	
Components of IAC features on CBCT			
IAC position			
Buccal	174 (58.0)	8 (29.6)	< 0.001
Inferior	89 (29.7)	4 (14.8)	
Lingual	31 (10.3)	14 (51.9)	
Inter-radicular	6 (2.0)	1 (3.7)	
IAC shape			
Round/oval	147 (49.0)	4 (14.8)	< 0.001
Tear-dropped	112 (37.3)	11 (40.7)	
Dumbbell	41 (13.7)	12 (44.4)	
Number of roots with perforated IAC[a]			
None	100 (33.3)	4 (14.8)	< 0.001
1	161 (53.7)	11 (40.7)	
2	39 (13.0)	10 (37.0)	
3	0 (0.0)	2 (7.4)	

CBCT cone-beam computed tomography, *IAC* inferior alveolar canal, *IANI* inferior alveolar nerve injury, *IVS* intravenous sedation

[a]Cochran-Armitage test for trend in proportions

Table 2 Logistic regression models to measure the association between inferior alveolar nerve injury and study variables

Variable	Univariate		Multivariate #1[b]		Multivariate #2[c]		Multivariate #3[c]	
	(Patient-based)		(Patient-based)		(Patient-based)		(Tooth-based)[d]	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Patients' demographics								
Age								
≤ 30 years	Ref.		Ref.		Ref.		Ref.	
> 30 years	4.54 (1.51–13.60)	0.007	4.19 (1.24–14.21)	0.021	4.99 (1.53–16.30)	0.008	4.55 (1.57–13.20)	0.005
Sex								
Male	Ref.							
Female	2.01 (0.80–4.99)	0.134						
Situations of surgery[a]								
Anesthesia								
General anesthesia or IVS	Ref.							
Local	0.51 (0.21–1.21)	0.125						
Operator								
Resident or Graduate fellow	Ref.							
Staff	1.41 (0.50–3.92)	0.510						
Extraction side								
Left	Ref.							
Right	0.66 (0.28–1.53)	0.334						
Anatomical classification of 3rd molars[a]								
Class								
I/II	Ref.		Ref.					
III	2.44 (1.01–5.89)	0.047	0.98 (0.33–2.90)	0.968				
Position								
A/B	Ref.		Ref.					
C	2.43 (0.89–6.62)	0.082	2.38 (0.70–8.16)	0.166				
Components of IAN features on CBCT[a]								
IAC position								
Buccal/inferior	Ref.		Ref.		Ref.		Ref.	
Ligual/inter-radicular	10.70 (4.38–26.10)	<0.001	6.13 (2.21–16.98)	< 0.001	7.21 (2.67–9.40)	< 0.001	6.15 (2.45–15.50)	< 0.001
IAC shape								
Non-dumbbell	Ref.		Ref.					
Dumbbell	5.17 (2.15–12.40)	< 0.001	1.80 (0.56–5.75)	0.322				
Number of roots with perforated IAC								
None or single	Ref.		Ref.		Ref.		Ref.	
Multiple	6.05 (2.50–14.70)	< 0.001	3.61 (1.05–12.38)	0.041	3.72 (1.29–10.70)	0.015	3.60 (1.36–9.53)	0.010

CI confidence interval, *IAC* inferior alveolar canal, *OR* odds ratio, *Ref.* reference

[a]Target tooth per case with bilateral surgeries to avoid analysis of duplication in patient-based analysis

[b]All variables with a *P* value of < 0.1 in the univariate model were simultaneously subjected

[c]Backward stepwise method

[d]Allow duplicate cases

Table 3 Definition of risk scores for inferior alveolar nerve injury

Variable	β^a	Score
Increased age (> 30 years)	1.61	2
Lingual/inter-radicular position of IAC	1.98	2
Multiple roots with perforated IAC	1.31	1
		Total 5

IAC inferior alveolar canal

[a]Regression coefficients of significant risk factors in the multivariate model #2 in Table 2 for conversion into adjusted integers (rounding) [20]

perforated IAC. Of these three variables showing significant association with IANI-risk on univariate logistic analysis, the first and last variables also were independent predictors on multivariate analysis, although not the second variable.

First, the buccolingual position of IAC to the LM3 roots has been reported to affect IANI probability. An elevator for tooth extraction inserted into the buccal side of the periodontal LM3 space would generate a compressive load that acts on the IAN, particularly on the lingual side or in the inter-radicular IAC position [7, 12, 24]. Second, the IAC shape was considered to reflect the severity of compressed deformation in IAC caused by proximity of LM3 roots. Using a multivariate logistic regression model, some reports [10, 15] stated that the most severe IAC deformation (dumbbell-shaped) was associated with IANI, whereas the others [11] failed to present the deformation as the significant predictor which agreed with our results. Lastly, several studies reported that cortical IAC perforation on CT was associated with risk for intraoperative nerve exposure [28, 29] and post-operative IANI [9–11, 15, 30]. Selvi et al. [11] quantitatively showed the greater the risk of IANI, with the longer distance of IAC perforation on coronal CT. We used the number of contacts between the roots and IAC with cortical perforation, and revealed that the finding of multiple contacts was a new predictive factor of IANI, although quantitative assessment of the perforated length on multiple sites was beyond the scope of this study. In extraction of LM3 with multiple roots close to the IAC, the roots should be removed following separation. Even with such careful attention, removal of those multiple roots has a high chance of load on the IAC, compared to the LM3 formed by a single root. Uncommonly, a dental deformity, such as taurodontism, with short or divergent roots would be difficult to separate appropriately [31]. Thus, the load from an elevator acting on the roots probably impinged on IAC from the diverse directions. On the other hand, three patients suffered IANI despite having intact cortical IAC on CBCT. This may be attributed to the minor destruction of the cortex, compressing the nerve by the transmitted forces or movements from the root.

Table 4 Association between the presence of inferior alveolar nerve injury and its risk score

Scoring system	IANI, *n* (%)		OR (95% CI)	*P* value
	Absence, *n* = 235	Presence, *n* = 25		
0	85 (36.2)	1 (4.0)	Ref.	
1	13 (5.5)	0 (0.0)	N/A	N/A
2	115 (48.9)	7 (28.0)	5.17 (0.63–42.85)	0.128
3	8 (3.4)	6 (24.0)	63.75 (6.80–597.42)	< 0.001
4	8 (3.4)	6 (24.0)	63.75 (6.80–597.42)	< 0.001
5	6 (2.6)	5 (20.0)	70.83 (7.09–707.30)	< 0.001

CI confidence interval, *IANI* inferior alveolar nerve injury, *N/A* not applicable, *OR* odds ratio, *Ref.* reference

Table 5 Diagnostic values of inferior alveolar nerve injury-risk scoring system in each cutoff point

IANI-RSS (0–5)	Sensitivity (%)	Specificity (%)	PPV[a] (%)	NPV[a] (%)	PLR	NLR	Youden index[b]
1–5 vs 0	96.0	36.2	4.3	99.7	1.50	0.11	0.32
2–5 vs 0, 1	96.0	41.7	4.7	99.7	1.65	0.10	0.38
3[c]–5 vs 0–2	68.0	90.6	17.8	99.0	7.23	0.35	0.59
4, 5 vs 0–3	44.0	94.0	18.0	98.3	7.39	0.60	0.38
5 vs 0–4	20.0	97.4	18.7	97.6	7.69	0.82	0.17

IANI-RSS inferior alveolar nerve injury-risk scoring system, *NLR* negative likelihood ratio, *NPV* negative predictive value, *PLR* positive likelihood ratio, *PPV* positive predictive value

[a]Adjusted by the overall incidence of IANI (2.9%)

[b]Calculated by sensitivity + specificity − 1

[c]Cutoff score of 3 for stratification into the high- and low-risk of IANI corresponding to a maximum of Youden index

Regarding association of increased age with IANI, Selvi et al. [11], Korkmaz et al. [8], and our study showed its significance using multivariate logistic analysis, which was contrary to other studies showing no significance [7, 10]. The age-dependent increase in IANI-risk may be ascribed to disadvantageous factors associated with aging, including decreased bone elasticity, enhanced tooth hypercementosis, narrowed periodontal space, sclerotic changes of surrounding bone, and delayed regeneration process of the injured nerve [2, 23]. Kajolle and Bjornland [32] demonstrated that IANI was more persistent in patients aged > 30 years. Considering increased age as a risk factor removal of impacted LM3 accompanied by potential future trouble, such as pericoronitis, dental caries, or root resorption of the anterior tooth [33], may be recommended before IANI-risk would increase in patients > 30 years old.

In grading study variables, accurate quantification of surgery-related factors would be difficult because the quality of an operation depends on the technical skills and clinical experience of surgeons. IANI-risk reportedly decreased in experienced hands [2], whereas no significant association between surgeon's experience and IANI incidence was noted in our study, which is in line with other reports [4, 7, 34].

Applying a scoring system of REDI-AO formula with six elements presented by Tolstunov [16] might improve estimation of IANI-risk, although not statistically verified using clinical samples. IANI-RSS consisted of three predictors based on our retrospective study, showed the area under the ROC curve of 0.83 with "good" performance, and displayed diagnostic values of sensitivity (68.0%), specificity (90.6%), PPV (17.8%), and NPV (99.0%) at a cutoff 3 score.

Generally, IANI after LM3 occurs infrequently, resulting in a relatively low level of PPV as previously reported [17]. Here, even the high-risk group showed not > 20% PPV adjusted by the overall incidence of 2.9%. Nonetheless, a relatively high PLR (7.23) value at the cutoff score of the IANI-RSS suggested its powerful index property for preoperative assessment of IANI, unlike limited diagnostic performance of panoramic tomography (range 1.36–5.64 of PLR) [35].

Our study included some limitations, mainly attributed to the retrospectively case-controlled approach. Not all patients who underwent impacted LM3 extraction were included because oral surgeons selected patients for additional CBCT scan when necessary. Owing to the random selection of controls, the charts of the nonselected individuals in the pool were not fully checked; however, approximately 1:9 case/control ratio, similar to that in a study reporting panoramic findings related to IANI by Szalma et al. [18], may provide robust results regarding the identified risk factors. As an additional limitation, IANI-RSS was primarily intended to stratify only IANI-risk from our limited data that depended on the low frequency of IANI. Therefore, validation studies are needed to determine its usefulness.

In conclusion, our study identified three risk factors for IANI after LM3 surgery: lingual/inter-radicular IAC position to LM3, multiple roots with perforated IAC, and increased age (> 30 years). Oral surgeons should raise awareness of the increasing probability in IANI after LM3 surgery in patients stratified into the high-risk group of the IANI-RSS, such as having multiple of the aforementioned factors.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the internal review boards (H30-E27) and was conducted in accordance with the Declaration of Helsinki.

Informed consent The requirement to obtain informed consent was waived by the internal review boards because of the retrospective design.

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