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Evaluating the risk of post-extraction inferior alveolar nerve injury through the relative position of the lower third molar root and inferior alveolar canal

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Abstract. The aim of this study was to introduce a method to evaluate the risk of inferior alveolar nerve (IAN) injury following the extraction of impacted lower third molars. Two hundred impacted lower third molars adjacent to the IAN were evaluated. These were divided into four classification groups according to preoperative cone beam computed tomography (CBCT) findings: AR, apical region; LT, lateral region of the tapered root; LE, lateral region of the enlarged root; AE, adjacent to the enlarged root. All teeth were dislocated along the long axis or arc of the root by tooth sectioning technique and extracted by a single surgeon. The primary outcome variable was postoperative neurosensory impairment of the IAN. The χ^2 test was used to evaluate differences in postoperative IAN injury between the classifications. Logistic regression analysis was used to evaluate the risk factors for postoperative IAN injury. The overall incidence of postoperative IAN injury was 7%. Specifically, most injuries involved classification AE (AE 36%, LE 8.6%, LT 3.6%, AR 0%), and the difference was statistically significant ($P < 0.05$). Logistic regression showed that classification AE was the only risk factor for postoperative IAN injury ($P < 0.001$). According to preoperative CBCT, the risk of postoperative IAN injury is higher when the IAN is adjacent to the enlarged part of the root.

Key words: lower third molars; CBCT image; inferior alveolar nerve injury.

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Inferior alveolar nerve (IAN) injury is one of the most serious complications after impacted lower third molar (LM3) extraction. According to previous reports, the frequency of postoperative IAN injury ranges from 0.4% to 8%, with less than 1% reporting permanent numbness[1,2]. However, the probability of injury could be more than 10% in higher-risk individuals[3,4].

Clinical studies have investigated the risk factors related to IAN injury, such as age, sex[5,6], the depth of impaction, and angulation[7,8]. It has also been reported that the proximity of the LM3 to the inferior alveolar canal (IAC), the relative position between the IAC and the roots of the LM3, and the shape of the IAC in the coronal plane on cone beam computed tomography (CBCT) are important factors for postoperative IAN injury[3,4,9–14]. Shiratori et al.[14], in a study involving 169 LM3 surgeries, reported that the incidence of IAN injury was higher in cases exhibiting an absence of cortication and a dumbbell-shaped IAC. Furthermore, Xu et al.[13] reviewed 537 LM3 extractions in which there was intersection with the IAC and found that the rate of IAN injury increased when the IAC was located lingual to the roots.

However, as the relative positions of the IAC and roots change constantly during tooth dislocation, images obtained in the coronal position may only provide part of the necessary information. Moreover, the direction of tooth dislocation also plays a role in IAN injury. For example, if the tooth is only dislocated along the long axis of the root, compression to the lateral side of the socket and IAN injury would appear avoidable. Unfortunately, previous studies have failed to elucidate this. Therefore, the aim of the present study was to propose a method to evaluate the risk of post-extraction IAN injury through assessment of the relationship between the LM3 root and the IAC in a plane that transects both the long axis of the root and the IAC, with all teeth involved dislocated along the long axis or arc of the roots.

Materials and methods

This retrospective study was performed in accordance with the Declaration of Helsinki on medical protocol and ethics and with the approval of the Ethics Review Board of Peking University School and Hospital of Stomatology.

Patients

All patients included in this study attended the Department of General Dentistry, Peking University School and Hospital of Stomatology, from January 2016 to February 2018.

The inclusion criteria for patient recruitment were as follows: patient age >20 years; all teeth involved either mesio-angularly (MI) or horizontally impacted (HI) according to the Winter classification; roots of the teeth adjacent to the IAC and no bony tissue between the roots and IAN as diagnosed by preoperative CBCT; the patient did not complain of paresthesia in the lower lip, gum, or teeth (all innervated by the IAN) before the operation. All teeth were extracted by the same surgeon using the same instruments.

CBCT analysis

Initially, the relative positions of the impacted LM3 and IAC, the shape of the IAC, and the length of the cortical bone defect were analysed according to previous research[9–12].

Next, the horizontal plane and the sagittal plane were adjusted according to the relative position of the LM3 and IAC in the coronal plane. When the IAC was located underneath or between the roots, the sagittal plane was adjusted to transect the long axis of the roots and the adjacent IAC and was used as a reference plane (Fig. 1). When the IAC was located laterally, the horizontal plane was adjusted to transect the long axis of the roots and the adjacent IAC and was set as a reference plane (Fig. 2).

Lastly, two lines vertical to the long axis of the tooth were set as reference lines. The apical line went through the root end and the enlargement line went through the enlarged parts of the root. The teeth were divided into four groups according to the relative position of the IAC and the reference lines: AR, apical region; LT, lateral region of the tapered root; LE, lateral region of the enlarged root; AE, adjacent to the enlarged part.

Surgery

All surgical procedures were performed by an experienced surgeon with the patient under local anaesthesia (4% articaine and epinephrine 1:1000.000), using similar surgical instruments, rotary and irrigation devices, and materials (sutures and haemostatic agents) in each case. Before surgery, the patient was informed of possible complications, including the possible risk of nerve damage during the procedure, and provided full informed consent.

After flap elevation and bone removal, the crown of the tooth was removed by a T-shape coronectomy. To control the direction of root dislocation, a narrow groove perpendicular to the long axis of the root was prepared, which began 2–3 mm apical to the remnant cervical margin on the distal surface of the LM3, and deeply to the root bifurcation (Fig. 3). Subsequently, a Winter elevator was placed at the groove and rotated mesially, mesio-lingually, or mesio-buccally according to the long axis or arc of the root, after which the whole or the mesial root was dislocated from the socket. The residual distal root could also be removed with the same procedure for multi-root LM3.

The duration of surgery from the beginning of the incision to wound closure was recorded.

Neurosensory assessment

A neurosensory assessment was performed by a surgeon who did not take part in the classification of the teeth. Sensation was evaluated by subjective monitoring of feelings in the vestibular gum, teeth, lower lip, and chin (all innervated by the IAN) preoperatively and at 1, 7, 30, and 90 days after extraction. In addition, the two-point discrimination test and von Frey filaments (NC12775-99; North Coast Medical, Morgan Hill, CA, USA) were used for objective evaluation. Preoperative results were recorded as the baseline. Patients with either subjective or objective abnormalities were regarded as having a postoperative IAN injury.

Statistical analysis

IBM SPSS Statistics version 19.0 (IBM Corp., Armonk, NY, USA) was used for the data analysis. The primary outcome was postoperative neurosensory impairment of the IAN, and the secondary outcome was the risk factors for IAN injury. The differences in postoperative IAN injury rates between the groups were analysed by χ^2 test. Furthermore, the differences in other variables such as sex, type of impaction, the distribution of lingually located IAC, dumbbell-shaped IAC, age, cortical defect length, and duration of the operation between the groups were analysed by χ^2 test and one-way analysis of variance (ANOVA). In addition, risk factors for postoperative IAN injury were analysed by logistic regression model, with classification AE or not, lingually located IAC or not, and dumbbell-shaped IAC or not. The difference was considered statistically significant when the *P*-value was less than 0.05.

Results

A total of 166 patients (200 teeth) were included in this study. IAN injury was detected in association with 14 teeth (7%). All patients attended the postoperative reviews on days 1, 7, and 30. Only

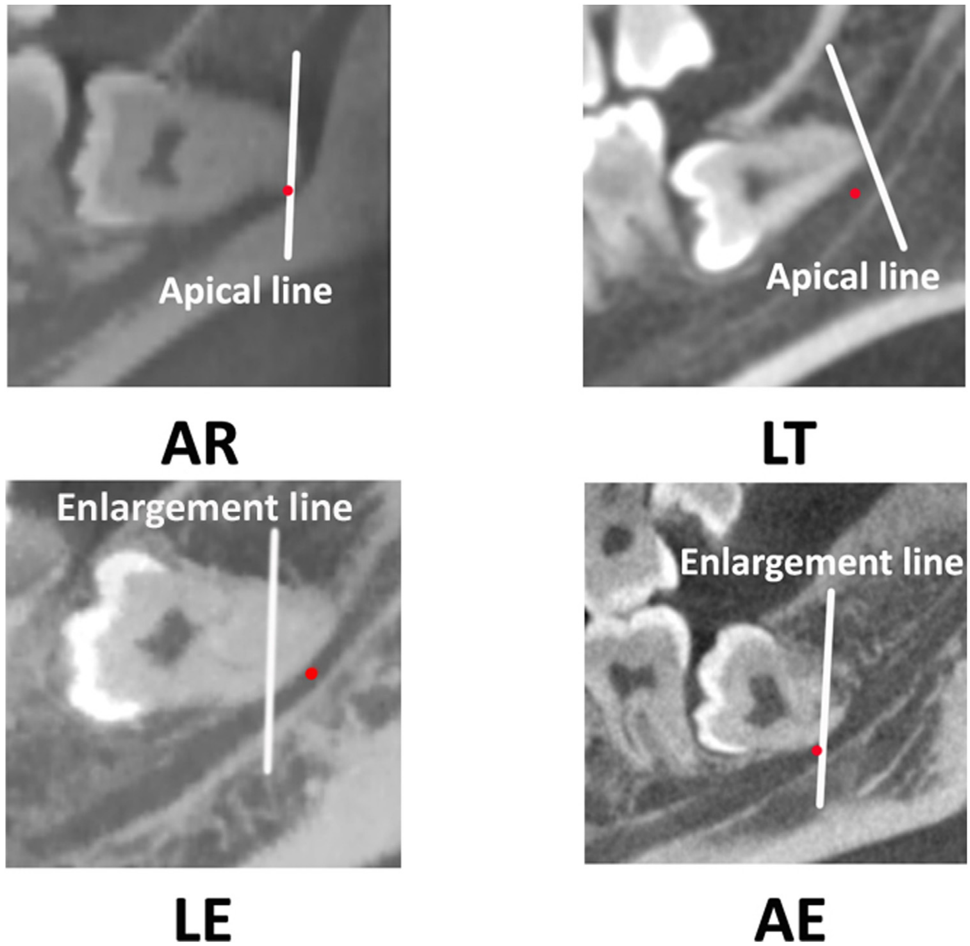

Fig. 1. When the inferior alveolar canal (IAC) was located underneath the roots, the sagittal plane was adjusted to transect the long axis of the roots and the adjacent IAC. The red point shows the narrowest part of the IAC that was adjacent to the roots. AR: the narrowest part of the IAC crosses the apical line; LT/LE: the narrowest part of the IAC is located coronal to the apical line (LT, tapered root; LE: enlarged root); AE: the narrowest part of the IAC is located at or coronal to the enlarged part.

patients with an IAN injury attended the follow-up at 90 days postoperative. All injuries were diagnosed within the first 7 days postoperative. Most of the injuries had recovered within 90 days postoperative (13/14). The exception was one patient in the AE group, whose injury had recovered fully at 5 months postoperative.

Table 1 shows the characteristics of the patients in each group. There was no statistically significant difference in age, sex, tooth angulation, or duration of the operation between the groups. However, there were significant differences in the cortical defect length ($P = 0.021$), the distribution of lingually located IAN ($P = 0.012$), and dumbbell-shaped IAC ($P = 0.001$).

The postoperative IAN injury rate in each group was as follows: AE 36%, LE 8.6%, LT 3.6%, and AR 0%. The difference was statistically significant, not only between the AE group and the other groups (AR, $P < 0.001$; LT, $P < 0.001$; LE, $P = 0.022$), but also between the LE group and the AR group ($P = 0.024$ Table 2).

As the distribution of lingually located IAC and dumbbell-shaped IAC differed between the groups, a logistic regression model was applied with AE classification or not, lingually located IAC or not, and dumbbell-shaped IAC or not. The results showed that only the AE classification was a risk factor for postoperative IAN injury ($P < 0.001$) (Table 3).

Discussion

This study introduced a method to evaluate the risk of post-extraction IAN injury through the relationship between the roots of the LM3 and IAC based on CBCT. All teeth involved were HI or MI for the following reasons. First of all, these classifications of impaction are more common in the study clinic, and the sample sizes of the other classifications would have been too small to analyse. Second, MI and HI are also regarded as risk factors for postoperative IAN injury[8]. Finally, the direction of tooth dislocation for other impactions is different from that of MI and HI. However, the conclusions of this study could also be applied to other impactions, as long as the tooth is dislocated along the long axis or arc of the roots.

The incidence of IAN injury after LM3 extraction could be more than 10% in high-risk individuals[3,4]. In particular, the most important factor for IAN injury is the anatomical relationship between the impacted LM3 and the IAC. Previous studies have discussed the IAN injury rate according to CBCT features and the results have implied that those with a lingually located IAC with a dumbbell shape in coronal view on CBCT are more vulnerable to injury[3,4,9,12–14]. Xu et al.[13] reviewed 537 extractions of LM3 that were adjacent to the IAC and found that the IAN injury rate was 18.6% (16/86) when the IAC was located lingually to the roots, with an

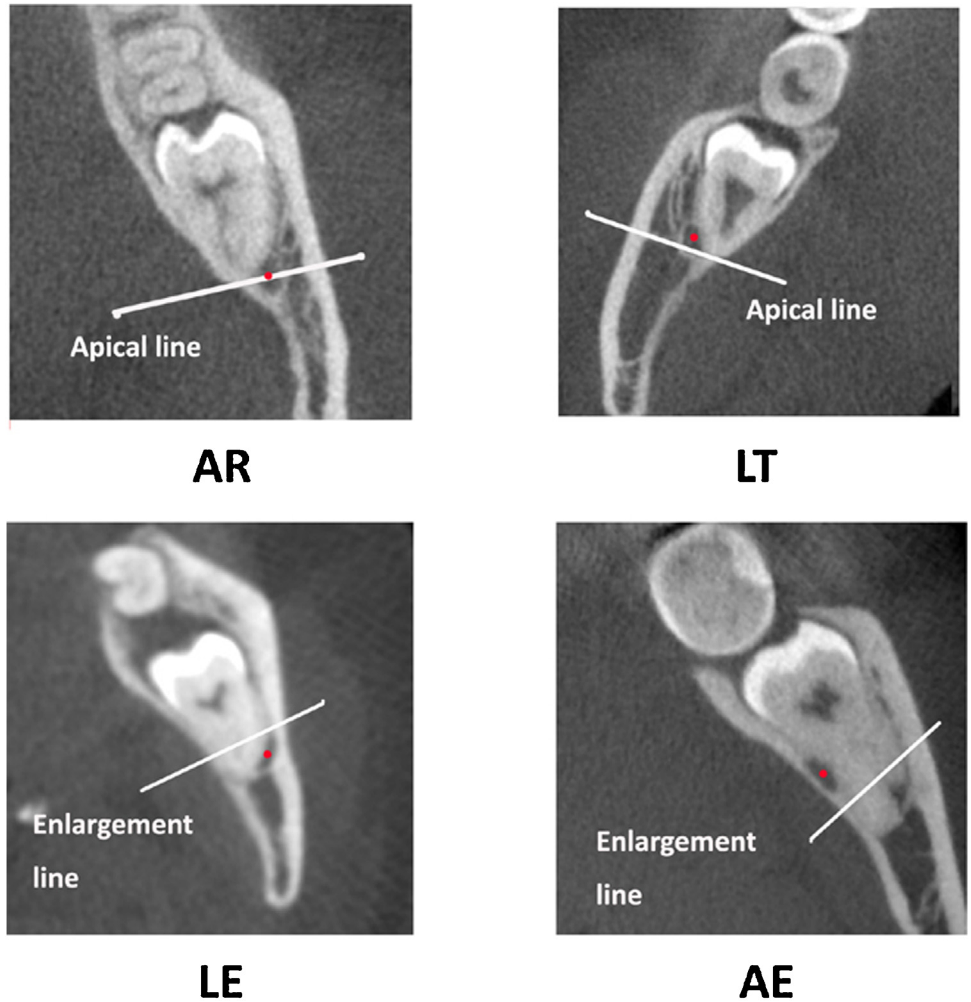

Fig. 2. When the inferior alveolar canal (IAC) was located lateral to the roots, the horizontal plane was adjusted to transect the long axis of the roots and the adjacent IAC. The red point shows the IAC adjacent to the roots. AR: the IAC crosses the apical line; LT/LE: the margin of the IAC is located coronal to the apical line (LT, tapered root; LE: enlarged root); AE: the centre of the IAC is located at or coronal to the enlarged part. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article).

overall injury rate of 6.1% (33/537). Their results were supported by those of Wang et al.[15]. Shiratori et al.[14], in a study involving 169 LM3 surgeries, reported that the incidence of IAN injury was higher in cases exhibiting an absence of cortication and a dumbbell-shaped IAC. Moreover, Tachinami et al.[16] found that IAN injury was more frequent in cases with all of the three factors (absent cortication, dumbbell-shaped IAC, lingually located IAC).

The predominance of IAN injury in lingually located cases has been closely related to the surgical approach. Generally, most of the extractions were managed through the buccal approach with an elevator located on the buccal side; therefore, the lingual tissue was inevitably compressed during extraction (Fig. 3). As the teeth in this study were dislocated along the long axis of the roots, it was assumed that the lingually located IAC was not the risk factor for IAN injury. Furthermore, although the distribution of lingually located IAC and dumbbell-shaped IAC differed significantly between the groups, the logistic regression analysis also indicated that these were not risk factors (Table 3).

Evaluating the risk of IAN injury mainly through coronal CBCT views is valuable but limited. To begin with, the direction of root dislocation also plays a role in postoperative IAN injury, and the risk increases if the tooth is dislocated towards the IAC (Fig. 3). However, as the shape of the alveolar socket is semi-elliptical or conical, compression of the IAN should be avoided as long as the tooth is dislocated along the long axis of the root (Fig. 3). Unfortunately, previous research has failed to take this key factor into consideration. Moreover, the relative positions of the roots and the adjacent IAC change constantly during tooth dislocation, thus assessment only through the coronal view will fail to reflect this information.

In the present study, the reference plane transected both the long axis of the roots and the adjacent IAC, and was used intuitively to evaluate not only the compression of the root to the IAC, but also the relative position between the root and the IAC during tooth dislocation. When the IAC was located in the apical region, the compression disappeared as soon as the root moved mesially, and IAN injury was not detected in this group. By contrast, if the IAC was adjacent to the enlarged parts of the root, compression was inevitable and the risk of IAN injury increased significantly. Notably, the injury still occurred even if the IAC was not adjacent to the enlarged root (LT and LE classification).

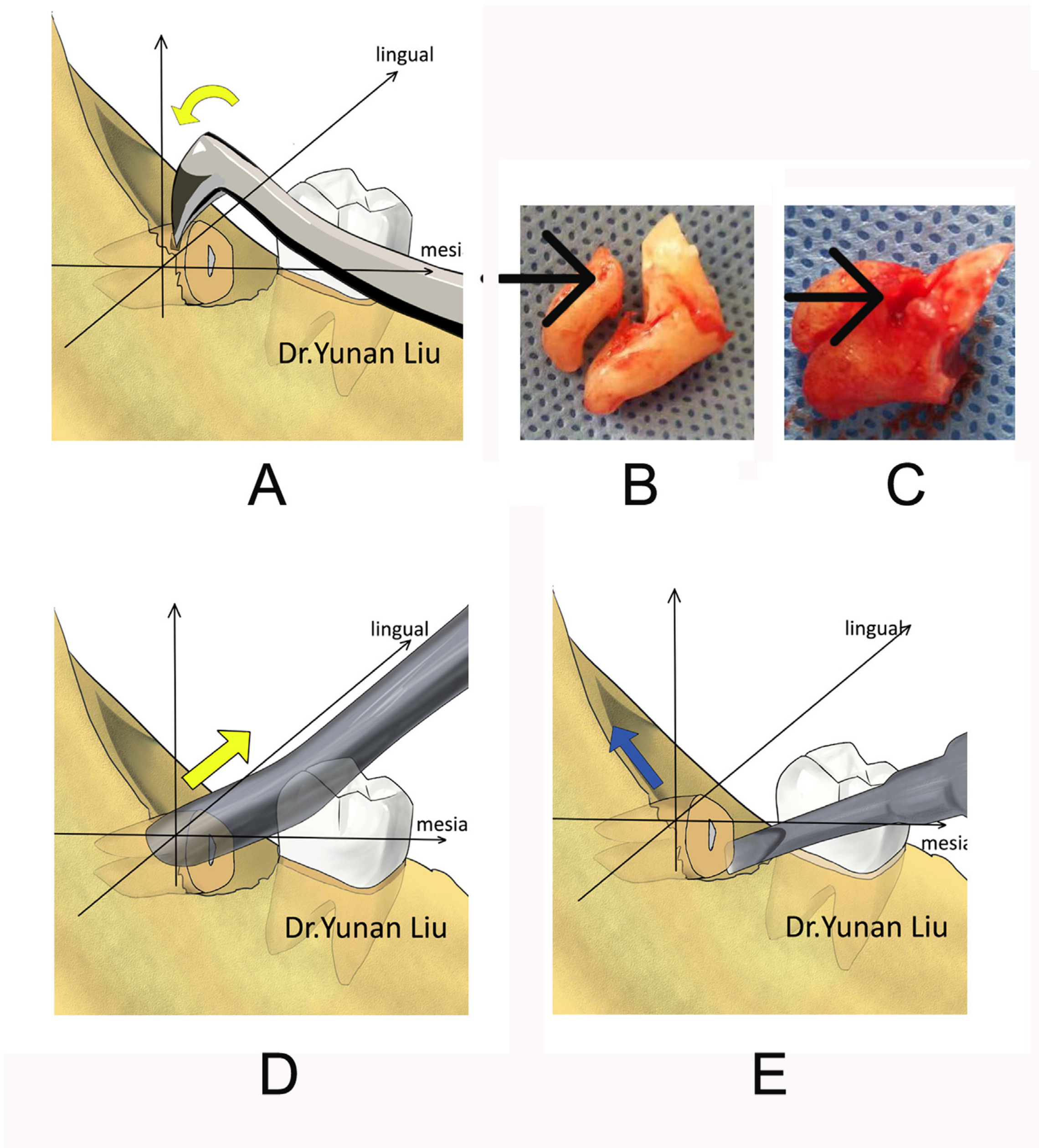

Fig. 3. Teeth dislocated in different directions. (A) Tooth dislocated along the long axis of the roots with a Winter elevator rotated mesially. (B) The groove (arrow) prepared for multi-root dislocation in this study. (C) The groove (arrow) prepared for single-root dislocation in this study. (D) Tooth dislocated lingually. (E) Tooth dislocated distally.

As shown in Table 1, the cortical defect length in the LT and LE groups was longer than that in the AR group and the incidence of IAN injury was also closely related to the length affected[12], and minimal deviation during toot dislocation might result in IAN compression. The study data showed a statistically significant difference in IAN injury between the LE and AR groups, but not between the LT and AR groups. As there were fewer cases in the LT group than in the AR group, a significant difference might have been found between the two groups with a larger sample size. Therefore, the direction of tooth dislocation should still be controlled precisely for teeth in the LT and LE classifications in order to relieve the pressure on the lateral side of the socket.

Recently, coronectomy has been suggested as a method to reduce the risk of IAN injury in LM3 extraction[17–21]. Pedersen et al.[17] followed up 231 LM3 coronectomies performed in 191 patients over a period of 5.7 years and reported an IAN injury rate of 1.3%. Furthermore, IAN injury was not detected in 116 coronectomies performed in 94 patients, as reported by Monaco et al.[18]. Although the effect of coronectomy has been shown to be acceptable, the indications for this procedure remain unclear and the possibility of postoperative infection and need for re-operation should not be ignored[18–20]. Monaco et al.[18] reported that 10 out of 116 teeth subjected to coronectomy required re-operation after 1 year of follow-up. Agbaje et al.[19] reported that the most common complications after coro-

Table 1. Characteristics of the study patients.

Category	Tooth classification[a]				*P*-value
	AR	LT	LE	AE	
Age (years)[b]	30.9 ± 7.3	29.8 ± 7	30.1 ± 7	32.1 ± 7	0.689
Sex					0.968
Male	21	15	10	4	
Female	50	31	23	12	
Tooth angulation					0.079
Mesial	48	30	19	7	
Horizontal	36	26	16	18	
Location of the IAC					0.012
Buccal	16	11	3	2	
Lingual	20	28	20	9	
Underneath	48	14	12	13	
Between	0	3	0	1	
Shape of the IAC					0.001
Round/oval	40	22	10	11	
Teardrop	21	11	8	5	
Dumbbell	23	23	17	9	
IAC defection (mm)[b]	3.5 ± 2.0	4.1 ± 1.6	4.4 ± 1.8	5.2 ± 2.0	0.021
Duration of operation (min)[b]	11.8 ± 4.1	10.5 ± 3.7	12.5 ± 2.8	13.0 ± 4.8	0.353
IAN injury	0	2	3	9	<0.001
Subjective	0	0	2	4	
Objective	0	2	3	9	

IAC, inferior alveolar canal; IAN, inferior alveolar nerve.
[a] AR, apical region; LT, lateral region of the tapered root; LE, lateral region of the enlarged root; AE, adjacent to the enlarged root.
[b] Mean ± standard deviation.

Table 2. Statistical differences in IAN injury rates between the groups; *P*-values.

Group	Tooth classification[a]			
	AR	LT	LE	AE
AR	–	0.158[b]	0.024[b]	<0.001[b]
LT	0.158[b]	–	0.225	<0.001
LE	0.024[b]	0.225	–	0.022
AE	<0.001[b]	<0.001	0.022	–

IAN, inferior alveolar nerve.
[a] AR, apical region; LT, lateral region of the tapered root; LE, lateral region of the enlarged root; AE, adjacent to the enlarged root.
[b] Evaluated by Fisher's exact test.

Table 3. Logistic regression analysis of the risk factors for IAN injury.

Factors	IAN injury		*P*-value
	Yes	No	
Lingually located IAC			0.129
Yes	9	68	
No	5	118	
Dumbbell-shaped IAC			0.108
Yes	10	62	
No	4	124	
AE classification			<0.001
Yes	9	16	
No	5	170	

AE, adjacent to the enlarged root; IAC, inferior alveolar canal; IAN, inferior alveolar nerve.

nectomy were root migration from the IAC, followed by root exposure, delayed healing/dry socket, and peri-apical infection, and re-operation was required in cases with root exposure and peri-apical infection. Therefore, the method was not well accepted by Chinese patients. According to the results of the present study, it is suggested that coronectomy might serve as an alternative procedure for those teeth classified as AE. For teeth with the LT and LE classification, the treatment plan should be established according to comprehensive factors such as surgeon experience, the patient's age, and the shape of the IAC.

In conclusion, for mesially and horizontally impacted LM3 that were adjacent to the IAC, a reference plane that transects both the long axis of the tooth and the IAC was valuable for preoperative evaluation. The incidence of postoperative IAN injury was higher when the IAC was adjacent to the enlarged parts of the roots. As the numbers of patients and cases with IAN injury in the LT and LE groups were limited, further prospective studies with a larger sample size are required to elucidate whether the LT or LE classification is a risk factor for postoperative IAN injury.

Funding

None.

Competing interests

None.

Ethical approval

The study involved human subjects. Ethical approval was given by the Ethics Review Board of Peking University School and Hospital of Stomatology (number PKUSSIRB-201837093).

Patient consent

Not required.

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