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Original Article

Use of panoramic radiography to predict postsurgical sensory impairment following extraction of impacted mandibular third molars

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Abstract

Background: The purpose of this study was to use panoramic radiographic findings to predict postsurgical sensory impairment following the extraction of impacted mandibular third molars.

Methods: There were 120 patients enrolled in this study (55 male and 65 female). A total of 120 impacted mandibular third molars were included due to the proximity between the inferior alveolar nerve (IAN) canal and the roots of the impacted third molar on the panoramic radiograph. Seven radiographic signs were the predictor variables: (1) darkening of the root(s); (2) interruption of the radiopaque line of the inferior alveolar canal; (3) diversion of the inferior alveolar canal; (4) dark and bifid apex; (5) deflection of the root(s); (6) narrowing of the inferior alveolar canal; and (7) narrowing of the root(s). The outcome variable was the postoperative IAN sensory impairment. The retrospective cohort study model was used, and univariable and bivariable statistics was computed with the statistically significant level at $p \leq 0.05$.

Results: Three of the radiographic signs were statistically associated with IAN sensory impairment ($p < 0.05$). They include: (1) interruption of the radiopaque line [sensitivity = 0.92, specificity = 0.45, positive predictive value (PPV) = 0.17, negative predictive value (NPV) = 0.02]; (2) diversion of the IAN canal (sensitivity = 0.77, specificity = 0.84, PPV = 0.37, NPV = 0.03); and (3) narrowing of the IAN canal (sensitivity = 0.69, specificity = 0.65, PPV = 0.19, NPV = 0.05). However, the other four radiographic signs, namely darkening of the root(s), dark and bifid apex, deflection of the root(s), and narrowing of the root(s), were not statistically associated with IAN sensory impairment ($p > 0.05$).

Conclusion: There are three radiographic signs: (1) interruption of the radiopaque line; (2) diversion of the IAN canal; and (3) narrowing of the IAN canal. These signs are valuable in presurgical evaluation of the risk of postoperative sensory impairment after surgical removal of impacted mandibular third molar.

Keywords: inferior alveolar nerve; mandibular third molar; panoramic radiograph; sensory impairment

1. Introduction

Extraction of impacted mandibular third molars (M3s) is the most common minor dentoalveolar surgery in a dental office. Some complications may be encountered during the peri- and postoperative period. One of them is postsurgical sensory impairment, which is rare but possibly irreversible. Complication rates of IAN damage resulted from a mandibular M3 extraction have been reported to range from 0.5% to 5%, while permanent IAN damage was <1%.[1–3] To avoid these postsurgical complications, many risk factors associated with M3 removal have been suggested, including the surgeon's experience, method of anesthesia, patient's age, tooth morphology, and the root proximity to the IAN canal.

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

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The intimate anatomic relationship between the M3 root and the IAN has been proposed in the past decades to be one of the major risk factors[4,5] for postsurgical sensory impairment. Therefore, many imaging techniques have been developed to assess the precise anatomic location of the M3, such as the periapical film, dental panoramic film, cross-sectional plane tomography,[6] computed tomography (CT),[7–10] and magnetic resonance imaging (MRI).[11] Among these imaging techniques, only MRI provides the true anatomic position of the inferior alveolar neurovascular bundle. However, it is also the most expensive and time-consuming imaging technique. Consequently, MRI is not a practical imaging technique for preoperative assessment during routine impacted M3 removal surgery. All the other imaging techniques (periapical film, dental panoramic film, cross-sectional plane tomography, and CT) can only indirectly identify the anatomic location of the IAN by tracing the outer cortex of the IAN canal. Although the periapical film produces the most detailed image of the M3 root morphology and its surrounding structures at the highest resolution [14–20 line pairs (lp)/mm], the actual film placement is often hindered by the patient's gag reflex and other oral structures, such as the tongue base or the floor of mouth. Even though the periapical film is the least costly and the most readily available in every dental clinic, it is not routinely used for the evaluation of the anatomic relationship between the M3 root and the IAN canal. Cross-section plane tomography could be a good choice during the preoperative work-up, because it provides not only the proximity but also the buccolingual relationship between the M3 root and the IAN canal. However, it is not widely accepted by most dentists and oral maxillofacial surgeons probably due to its blurry image quality and the difficulty in differentiating between the IAN canal and the porosity of the bone marrow space.

By the early 2000s, CT was introduced and utilized in dentistry to evaluate the anatomic relationship between the M3 root and the IAN canal. More recently, the 3-dimensional reconstruction images showing the relationship between the M3 root and the IAN canal have become available using cone-beam CT.[12] Meanwhile radiation exposure is greatly reduced with cone-beam CT compared with conventional CT. New cone-beam CT represents an imaging modality that is near ideal for assessing the proximity between the M3 root and the IAN canal. Unfortunately, this technology is still not widely used in developing countries, perhaps because of the high costs associated with cone beam CT are often a deterrent to the practicing dentist. In addition, the possibility of more radiation exposure may also be of great concern to some patients. When taking into account the cost-benefit effect, and the information that the image itself provides, it is no surprise that panoramic radiography is still so commonly used by most dentists and oral surgeons for assessing the intimate relationship between the M3 root and the IAN canal.

The reliability of panoramic radiography for predicting the relationship between the M3 root and the IAN canal is still somewhat controversial.[13–20] Seven radiographic signs (Table 1) are proposed to predict postsurgical IAN injury during the removal of an impacted mandibular M3. According to the literature, the estimated sensitivity of the radiographic signs as a predictor for the IAN damage ranges from 66% to 79%, while the specificity ranges from 39% to 86%.[14,16,19] The visual proximity between the M3 root and the IAN canal on a panoramic radiograph is always suggestive of a higher risk of postsurgical IAN injury. Since most dentists use panoramic radiography as an assessment tool for impacted M3 removal surgery, the accuracy of this imaging modality needs to be closely examined.

Table 1
Radiographic signs of the intimate relationship between the M3 root and inferior alveolar nerve canal.

Radiographic signs	Description
Darkening of the M3 root	Radiolucency of the M3 root area, where M3 root and mandibular canal are superimposed
Interruption of the radiopaque line	Absence of continuity of mandibular canal cortex
Diversion of the mandibular canal	Obviously direction change of the mandibular canal in passage of the M3 root
Dark and bifid apex	Bifid and darkening of the M3 root, where mandibular canal is superimposed to it
Deflection of the root	Dilaceration root morphology of M3, where mandibular canal is contact or superimposed to it
Narrowing of the mandibular canal	Narrowing of the mandibular canal dimension where the canal and M3 root are contact or superimposed
Narrowing of the root	Narrowing of the M3 root, where the mandibular canal and M3 root are contact or superimposed
Other positive radiographic findings	Any other significant pathological change in M3 area

The purpose of this study is to determine whether a correlation exists between the radiographic risk factors and postsurgical sensory impairments. We hypothesize that the positive radiographic findings increase the possibility of postsurgical sensory impairment. Each individual parameter is statistically examined to testify its association with the sensory impairment with its respective sensitivity and specificity.[13–20]

2. Methods

A total of 120 patients, who consulted the Oral and Maxillofacial Surgery Department of Taipei Veterans General Hospital, Taipei, Taiwan for the extraction of impacted lower third molars from November 2008 to March 2009, were enrolled in this study. They were chosen due to close distance between the M3 root and the IAN canal on the panoramic radiograph. Informed consent was obtained from all of the patients. The sensory function of the IAN was assessed and confirmed to be intact for every patient before the surgical procedure. None of the patients had any neurological history. The epidemiological data collected included sex, age, and type of impaction tooth (Pell–Gregory Ramus and Occlusal Classification). Proximity was defined as either close (1 mm between M3 root and IAN canal upper cortex), in contact with (M3 root just touches the IAN canal upper cortex), or overlapping (M3 root superimposes the IAN canal). All M3s were removed by bur method with straight surgical handpiece. The surgical procedure was performed by three oral surgeons in the

Oral and Maxillofacial Surgery Department of Taipei Veterans General Hospital. Radiographs were read by two experienced oral surgeons independently, and the interexaminer reliability was calculated by κ statistics. This clinical survey was performed with all patients' approval. The result of patient outcome has no correlation to this study itself.

Seven radiographic signs represent the predictive variables, which include: (1) darkening of the root, which is radiolucency of the M3 root area, where M3 root and IAN canal are superimposed; (2) interruption of the radiopaque line which indicates the absence of continuity of the IAN canal cortex; (3) diversion of inferior alveolar canal, which suggests change in direction of the IAN canal when it courses near the M3 root; (4) bifid and darkening of the M3 root apex, where the IAN canal is superimposed onto it; (5) deflection of the root, which is dilacerated root morphology of M3, where the IAN canal is in contact with or superimposed onto it; (6) narrowing of the inferior alveolar canal, which is the narrowing of the IAN canal dimension where the canal and the M3 root are in contact or superimposed; and (7) narrowing of the root, which is the narrowing of the M3 root, where the IAN canal and M3 root are in contact or superimposed (Table 1).

The outcome variable was numbness on the ipsilateral lower lip, which was defined as sensory impairment compared with the sensation on the contralateral side. All patients were asked to record the recovery time of the inferior alveolar nerve block anesthesia, and they were followed-up 1 week later. At the 1-week follow-up appointment, cotton pliers were used to stimulate the five reference points on the lower lip bilaterally, and the difference in sensation between the five points on each side of the lip was recorded. If more than three points on the ipsilateral lip presented sensory impairment, the result was defined as positive sensory impairment after the ipsilateral lower M3 extraction. Appropriate descriptive and bivariate statistics were computed as needed. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were computed for each panoramic radiography sign. Fisher's exact test was used to access the data. Level of significance was set at $p \leq 0.05$. The data for statistical analysis were computed by SPSS version 14.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results

The study sample was composed of 120 patients with a mean age of 25.6 years, and 54% of the sample was male. The two surgeons evaluated a total of 120 impacted M3s independently, and the κ value was 0.76 in interexaminer agreement. Based on Pell−Gregory Classification, there were 28 Pell−Gregory Ramus Class I M3s (23.3%), 70 Class II M3s (58.3%), and 22 Class III M3s (18.3%); and 62 Pell-Gregory Occlusal level A M3s (51.7%), 43 Pell−Gregory Occlusal level B M3s (35.8%), and 15 Pell−Gregory Occlusal level C M3s (12.5%; Table 2). The frequencies of the panoramic radiographic signs were: (1) darkening of the root, 42 M3s (35.0%); (2) interruption of the radiopaque line, 70 M3s (58.3%); (3) diversion of the inferior alveolar canal, 27 M3s (22.5%); (4) dark and bifid apex, 25 M3s (20.8%); (5) deflection of the roots, 28 M3s (23.3%); (6) narrowing of the inferior alveolar canal, 46 M3s (38.3%); and (7) narrowing of the roots, 26 M3s (21.7%). Following M3 extraction, the IAN sensory impairment was observed in 13 (10.8%) patients based on the patients' own reports and was confirmed by our clinical neurosensory examination. All the cases of IAN injury resolved within 6 months. The frequency of the IAN sensory impairment in this study was 10.8% (Table 2). Three of the radiographic signs were statistically associated with IAN sensory impairment ($p \leq 0.05$), including interruption of the radiopaque line, diversion of the IAN canal, and narrowing of the IAN canal. However darkening of the root, dark and bifid apex, deflection of the root, and narrowing of the root were not statistically associated with IAN sensory impairment ($p > 0.05$; Table 3). Using interruption of the radiopaque lines to predict postsurgical IAN sensory impairment, the sensitivity was 0.92, specificity = 0.45, PPV = 0.17, and NPV = 0.02. The other significant radiographic predictive factors were diversion of the IA canal (sensitivity = 0.77, specificity = 0.84, PPV = 0.37, NPV = 0.03) and narrowing of IA canal (sensitivity = 0.69, specificity = 0.65, PPV = 0.19, NPV = 0.05), which are summarized in Table 4.

Table 2
General profile of patients, type of mandibular third molars and their radiographic features in relation to inferior alveolar nerve canal.

Number of patients	120
Mean age (y)	25.6
Sex (male:female)	65:55
Impaction type	
Pell−Gregory Ramus class I	28 (23.3)
Pell−Gregory Ramus class II	70 (58.3)
Pell−Gregory Ramus class III	22 (18.3)
Pell−Gregory occlusal level A	62 (51.7)
Pell−Gregory occlusal level B	43 (35.8)
Pell−Gregory occlusal level C	15 (12.5)
Radiographic risk factors	
Darkening of the root	42 (35.0)
Interruption of the white line	70 (58.3)
Diversion of inferior alveolar canal	27 (22.5)
Dark and bifid apex	25 (20.8)
Deflection of the root	28 (23.3)
Narrowing of the inferior alveolar canal	46 (38.3)
Narrowing of the root	26 (21.7)
Distance between IA canal and M3 root	
Closed	19 (15.8)
Contact	57 (47.5)
Overlapping	44 (36.7)
Number of IAN dysesthesia	13 (10.8)

Data are presented as *n* (%) unless otherwise indicated.
IAN = inferior alveolar nerve.

4. Discussion

Transient IAN sensory impairment after M3 removal is a common complication, although most of the patients recovered from the numbness on their ipislateral lower lip in a few months. However, the unpleasant sensation bothers not only the patient but also the dentist. The ability to prevent and

Table 3
Summary of the bivariate relationship between the risk factor variables (radiographic signs) and the outcome variable [inferior alveolar nerve (IAN) sensory impairment].

Radiographic risk factors	IAN numbness		
	Yes	No	Total
Darkening of the root			
Yes	7	35	42
No	6	72	78
Total, $p > 0.05$	13	107	120
Interruption of the white line			
Yes	12	58	70
No	1	49	50
Total, $p < 0.05$	13	107	120
Diversion of the IA canal			
Yes	10	17	27
No	3	90	93
Total, $p < 0.05$	13	107	120
Dark and bifid apex			
Yes	3	22	25
No	10	85	95
Total, $p > 0.05$	13	107	120
Deflection of the root			
Yes	4	24	28
No	9	83	92
Total, $p > 0.05$	13	107	120
Narrowing of the IA canal			
Yes	9	37	46
No	4	70	74
Total, $p < 0.05$	13	107	120
Narrowing of the root			
Yes	3	23	26
No	10	84	94
Total, $p > 0.05$	13	107	120

predict this complication is therefore a popular issue of clinical significance in dentistry. Studies have shown that nerve dysfunction following M3 surgery is the third most common complication after alveolar osteitis/dry socket and wound infection, with a incidence that ranges from 0.5% to 5%. Fortunately, postsurgical IAN sensory impairment is usually self-limiting in a few months. Etiologic factors associated with nerve injury include surgeon's surgical experience, age of the patient, tooth morphology and position/orientation (e.g., horizontally impacted, etc.), method of anesthesia, traumatic tissue manipulation, postsurgical edema or wound infection, and, most importantly, the anatomic proximity of the inferior alveolar nerve to the tooth. Panoramic radiography is the imaging modality that most dentists and oral surgeons use to observe the location of the impacted mandibular third molar and to assess the risk for IAN damage in M3 removal surgery. Seven radiographic signs have been proposed to predict the proximity between M3 and the IAN canal: (1) darkening of the root; (2) interruption of the radiopaque line; (3) diversion of the IAN canal; (4) dark and bifid M3 roots; (5) deflection of the M3 root; (6) narrowing of the IAN canal; and (7) narrowing of the M3 root. While all signs were found on the radiographs in our study, only three of them were statistically significantly related to IAN sensory impairment, including: (1) interruption of the radiopaque line; (2) diversion of the IAN canal; and (3) narrowing of the IAN canal. The results in our study seemed to be consistent with other studies on the association between radiographic findings and IAN injury. Our findings were in agreement with the work of Sedaghatfar et al,[16] which reported that: (1) darkening of the tooth root; (2) narrowing of the tooth root; (3) interruption of the radiopaque lines; and (4) diversion of the canal, were statistically associated with IAN exposure following M3 extraction. However, darkening of the tooth root was not statistically significant in predicting postoperative IAN sensory impairment in our study. Furthermore Nakagawa et al[18] used 3-dimensional CT to confirm the value of panoramic radiograph in predicting physical contact between M3 root and IAN canal. Bell et al's[14] study in 2003 also concurred with the results of Sedaghatfar et al's[16] study in 2005 and established a significant relationship between the three predictive variables (deflection of the root, darkening of the root, and interruption of the white line) and IAN exposure. While Bell et al[14] found an intimate relationship between M3 and IAN when deflection of the root and darkening of the roots were observed, we did not find deflection of the root and darkening of the roots to be a reliable predictor of IAN sensory impairment ($p = 0.357$ and $p = 0.116$, respectively) (Fig. 1).

The results of our study support the hypothesis that the PPV and NPV of the radiographic signs as markers for anatomic intimacy between M3 and the IAN would be useful in the presurgical predicting for potential chances of IAN sensory impairment. Previously in the literature, the PPV of the radiographic signs as markers of nerve injury ranged from 0.014 to 0.027, assuming a 1% prevalence of IAN injury. The PPVs in our study ranged from 0.12 to 0.37. Different from the previous literature, the NPVs in this study were low, indicating that, in the absence of positive radiographic signs, it is difficult to determine the true relationship between M3 roots and IAN canal.

Interestingly, among the seven radiographic signs in our study, only IAN canal-related factors, namely interruption of the radiopaque line and diversion and narrowing of the canal, were statistically significant in relation to postoperative IAN sensory impairment, whereas the M3 root related factors

Table 4
Using interruption of the radiopaque lines to predict postsurgical inferior alveolar nerve sensory impairment.

Risk factor variable	Outcome variable					
	Sensitivity	Specificity	PPV	NPV	Accuracy	p
Darkening of root	0.54	0.67	0.17	0.08	0.66	0.116
Interruption of the white line	0.92	0.45	0.17	0.02	0.51	0.007
Diversion of inferior alveolar canal	0.07	0.84	0.37	0.03	0.83	< 0.001
Dark and bifid apex	0.23	0.79	0.12	0.11	0.73	0.537
Deflection of the root	0.30	0.77	0.14	0.10	0.73	0.357
Narrowing of the inferior alveolar canal	0.69	0.65	0.19	0.05	0.66	0.018
Narrowing of the root	0.23	0.79	0.12	0.11	0.73	0.568

NPV = negative predictive value; PPV = positive predictive value.

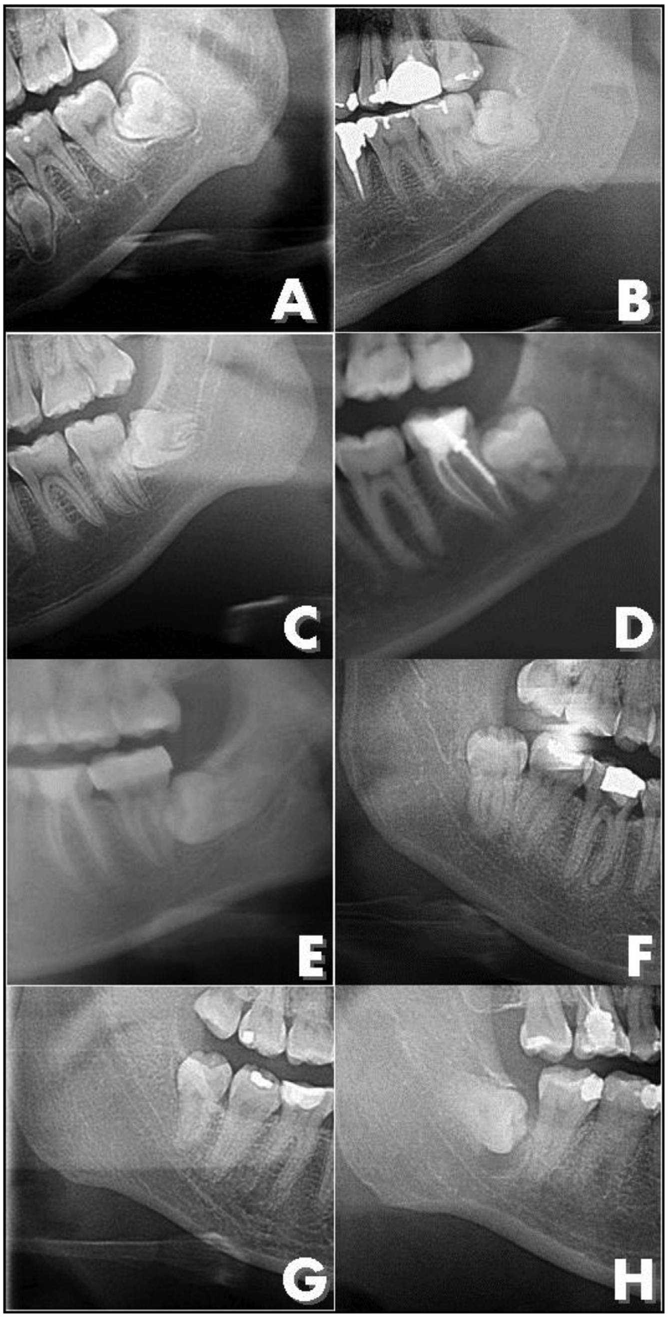

Fig. 1. (A) Darkening of root representing the radiolucency of the third molar (M3) root area, where M3 root and mandibular canal are superimposed. (B) Interruption of the radiopaque line representing the absence of continuity of mandibular canal cortex. (C) Diversion of inferior alveolar canal representing an obvious direction change of the mandibular canal in passage of the M3 root. (D) Dark and bifid apex of the M3 root where mandibular canal is superimposed to it. (E) Deflection of the root representing dilaceration root morphology of M3 where the mandibular canal is in contact with or superimposed onto it. (F) Narrowing of the mandibular canal dimension representing the canal and M3 root are closely in contact or superimposed. (G) Narrowing of the root representing narrowing of the M3 root where the mandibular canal and M3 root are in contact or superimposed. (H) Cystic change of the impacted mandibular third molar with tooth structure locating approximately close to the inferior alveolar nerve canal.

(darkening of the root, dark and bifid apex, deflection of the root, and narrowing of the root) were not statistically significant to postoperative IAN sensory impairment. It can be argued that the resolution of the detailed anatomy on the panoramic radiograph is not equal in the whole mandible, nor is it uniform on each machine. The resolution of a panoramic film is 1.2–1.5 lp/mm at the periphery of the focal trough, but increases to 3–5 lp/mm in the central part of the focal trough. Periapical film, however, can reach a resolution up to 14–20 lp/mm. Detailed root structures can be visible at the resolution of at least 3–5 lp/mm, but the resolution of the mandibular third molar area on the panoramic radiograph is not high enough to allow for the identification of detailed root morphology, such as darkening of the root, dark and bifid apex, deflection of the root, and narrowing of the root. Again, if the M3 roots curve buccally or lingually, the curvature of the roots is away from the line of the dental arch, which means that they are away from the highest resolution region on the panoramic film. This would be difficult in the interpretation of those roots images.

In conclusion, there are three radiographic signs: interruption of the radiopaque line, diversion of the IAN canal, and narrowing of the IAN canal, that are statistically significant to postoperative sensory impairment in our study. Our purpose is to predict the risk of postsurgical sensory impairment after the extraction of mandibular impacted M3s. Based on our study results, a more precise imaging modality, such as cone-beam CT, should be recommended to those patients whose panoramic radiographs show one or more radiographic signs. Fortunately, there are more powerful imaging tools such as cone-beam CT available today to help in identifying the real intimate relationship between the IAN canal and the M3 roots, if the preliminary panoramic radiographic results show a close relationship between these two anatomic landmarks. Therefore, panoramic radiography still serves as one of the most convenient tools in the extraction of impacted M3s when the more sophisticated and expensive cone-beam CT technology is not available or routinely used.

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