Panoramic Radiographic Findings as Predictors of Inferior Alveolar Nerve Exposure Following Third Molar Extraction

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Objectives: The aim of this study was to estimate the sensitivity and specificity of panoramic radiographic findings in relation to inferior alveolar nerve (IAN) exposure after mandibular third molar (M3) extraction.

Methods: The study used a retrospective cohort model. The primary predictor variable was the presence or absence of ≥ 1 panoramic radiographic sign associated with an increased risk for IAN injury. The secondary predictor variable was the surgeon's assessment of IAN exposure risk. The outcome variable was IAN exposure, defined as direct visualization of the IAN at the time of M3 extraction. Appropriate univariate and bivariate statistics were computed and the level of statistical significance was set at $P \leq .05$.

Results: The sample was composed of 230 patients having 423 mandibular M3s evaluated and removed. Following M3 extraction, the IAN was visualized in 24 (5.7%) extraction sites. Four of the radiographic signs were statistically associated with IAN exposure ($P \leq .05$). The sensitivities and specificities of the 4 radiographic findings ranged from 0.42 to 0.75 and 0.66 to 0.91. The clinician's preoperative estimate of the likelihood of IAN exposure was statistically associated with IAN exposure after M3 extraction ($P < .001$; sensitivity = 0.79; specificity = 0.86).

Conclusion: Four radiographic findings (darkening of the tooth root, narrowing of the tooth root, interruption of the white lines, and diversion of the canal) were statistically associated with IAN exposure following M3 extraction. The surgeon's overall estimate of risk based on the panoramic radiograph was also statistically associated with an increased risk of IAN exposure.

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Removal of mandibular third molars (M3) is one of the most common operations performed in the United States.[1] An infrequent, but serious complication associated with the removal of impacted mandibular third molars is inferior alveolar nerve (IAN) injury and associated neurosensory deficits. The reported frequency of IAN injury associated with M3 removal ranges from 0.6% and 5.3%. The risk of permanent IAN injury is less than 1%.[2-7] The risk of IAN injury is predicated on an intimate

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anatomic relationship between the impacted tooth and the nerve.

Currently, the panoramic radiograph is the imaging technique of choice to evaluate impacted M3s. The preoperative panoramic radiograph is also used to estimate the risk for IAN injury associated with M3 surgery.[8] The estimated sensitivity for radiographic signs as predictors of nerve injury range from 24% to 38%. The specificity ranges from 96% to 98%.[7,8] Given the high specificities, negative radiographic findings thus appear more useful for advising patients about the risk of IAN injury after M3 extraction than do positive radiographic findings.[7]

Anatomic intimacy between the IAN and M3 is a risk factor for IAN injury. Visualization of the IAN neurovascular bundle at the time of M3 surgery suggests anatomic intimacy and an increased risk for nerve injury. Experience suggests that visualization of the IAN neurovascular bundle occurs more frequently than IAN injury after M3 removal. Given a stable estimate of sensitivity and specificity, as the prevalence of a condition increases (eg, visualization of the IAN), the positive predictive value (ie, accuracy), improves.

The overall purpose of this study was to examine the association between previously documented panoramic radiographic signs associated with IAN injury risk after M3 removal and IAN exposure at the time of M3 removal.[8] We hypothesized that positive panoramic radiographic signs would be associated with an increased risk for IAN nerve exposure after M3 extraction. As such, the positive and negative predictive values of these radiographic signs as markers for anatomic intimacy between M3 and the IAN would be greater than for IAN injury alone. The specific aims of this study were to: 1) estimate the prevalence of IAN exposure and IAN injury after M3 surgery, 2) determine the association between panoramic radiographic signs and IAN exposure after M3 removal, 3) estimate the sensitivities and specificities of the various radiographic signs for IAN exposure, and 4) compute the positive and negative predictive values of the radiographic signs for IAN exposure.

Methods

To address our research purpose, we used a retrospective cohort study. The cohort was composed of patients presenting to the Oral and Maxillofacial Surgery Unit, Massachusetts General Hospital (Boston, MA) for extraction of 1 or more M3s by 1 of the 2 authors (M.A., T.B.D.) between July 1998 and July 2002.

STUDY VARIABLES

The primary predictor variable was presence or absence of 1 or more of the 5 panoramic radiographic signs associated with an increased risk for M3 injury assessed on a preoperative panoramic radiograph. Briefly, the first sign, *darkening of the root*, results from loss of root density in a tooth that is impinged upon by the canal. The second sign, *interruption of the white line,* is found when the radio-opaque lines that constitute the inferior alveolar canal are discontinuous because a tooth root lies within the canal. These white lines are "interrupted" if they disappear in the vicinity of the tooth. The third sign, *diversion/upward displacement of the inferior alveolar canal*, occurs when there is a change in direction as the canal crosses the M3. The fourth sign, *deflected roots*, refers to "hooking" of the root around the canal (seen on radiograph as an abrupt deviation of the root). The fifth sign, *narrowing of the root*, refers to narrowing of the tooth root where the canal crosses.[8]

A secondary predictor variable was the surgeon's assessment of the risk for IAN exposure after M3 surgery. After reviewing the radiograph, the surgeon was asked to predict the likelihood that the IAN would be exposed after M3 surgery. The variable was scored in a binary fashion as yes or no (ie, the surgeon expects or does not expect to visualize the IAN at the time of M3 removal).

Two surgeons (M.A., T.B.D.), blinded regarding the IAN exposure status, independently assessed preoperative panoramic radiographs for the presence of the 5 radiographic signs. To maintain blindness, each surgeon reviewed the panoramic radiograph of the other surgeon's patients. To measure intraexaminer and interexaminer variance, 50 radiographs were read twice by each surgeon independently, and the readings were separated in time by at least 1 month. The results of the first and second readings were compared and the kappa statistic calculated to estimate the interexaminer and intraexaminer reliability. The intraexaminer reliability measures for the 2 surgeons were 0.82 and 0.76. The interexaminer reliability was 0.85.

The outcome variable was IAN exposure, defined as direct visualization of the IAN at the time of M3 extraction. As part of the usual practice, the surgeons (M.A., T.B.D.) examined all extraction sites for the presence or absence of an exposed IAN. Specifically, the wound was copiously irrigated and under direct vision using a headlight, the extraction was inspected for evidence of IAN exposure. If the IAN was visualized following M3 extraction, the finding was recorded in the operative note.

Table 1. SUMMARY OF DESCRIPTIVE STATISTICS

Variable	
Sample size (no. of patients, k M3s)	230 patients (423 M3s)
Mean age (n)	24.0 ± 5.2 yrs
Gender—female (n)	138 (60.0%) female
Impaction type (k)	
Horizontal impaction	44 (10.4%)
Mesioangular impaction	220 (52.0%)
Vertical impaction	149 (35.2%)
Distoangular impaction	10 (2.4%)
Operation (k)	
Surgical extraction	18 (4.3%)
Nonsurgical extraction	20 (4.7%)
Soft tissue extraction	28 (6.6%)
Partial bony extraction	131 (31.0%)
Full bony extraction	226 (53.4%)
Radiographic findings (k)	
Darkening of the root	72 (17.0%)
Interruption of the white line	152 (35.9%)
Diversion of the IA canal	53 (12.5%)
Deflection of the root	59 (13.9%)
Narrowing of the root	50 (11.8%)
No radiographic findings noted	37 (8.7%)
Surgeon predicts IAN exposure—yes	75 (17.7%)
IAN exposure—yes	24 (5.7%)
IAN injury—yes	3 (0.7%)

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Data were collected for the following variables: age, gender, angulation, and level of impaction (classified using the Winter's Classification) of each tooth.

DATA ANALYSIS

Epi Info version 6.04b (Centers for Disease Control and Prevention, Atlanta, GA) was used to create a database and to analyze the data. Appropriate descriptive and bivariate statistics were computed as indicated. The sensitivity, specificity, positive predictor variable (PPV), and negative predictor variable (NPV) were computed for each panoramic radiographic sign and for the surgeons' assessment of risk. Level of statistical significance was set at $P \leq .05$.

Results

The study sample was composed of 230 patients with a mean age of 24.0 ± 5.2 years and 60% of the sample was female (Table 1). The 2 surgeons evaluated a total of 423 M3s. Based on Winters' classification, 44 M3s were horizontal impactions (10.4%), 220 were mesioangular impactions (52.0%), 149 were vertical impactions (35.2%), and 10 were distoangular impactions (2.4%). In 357 (84.4%) M3 extractions, bone removal with or without tooth sectioning was required to facilitate extraction.

The frequency of the panoramic radiographic signs were: 1) darkening of the root, n = 72 M3s (17.0%), 2) interruption of the white line, n = 152 M3s (35.9%), 3) diversion of the inferior alveolar canal, n = 53 M3s (12.5%), 4) deflection of the roots, n = 59 M3s (13.9%), and 5) narrowing of the roots, n = 50 M3s (11.8%). In reviewing the radiographs, the surgeons estimated that the IAN would be exposed in 75 (17.7%) extraction sites.

Following M3 extraction, the IAN was visualized in 24 (5.7%) extraction sites. Overall, 3 (0.7%) M3 sites had evidence of IAN injury based on patient report and confirmed with a neurosensory examination. All cases of IAN injury resolved within 1 year. The frequency of subsequent IAN injury after visualizing the IAN was 12%.

Table 2 summarizes the bivariate relationships between the predictor variables (radiographic signs and surgeon's prediction) and the outcome variable (IAN exposure). Four of the radiographic signs were statistically associated with IAN exposure ($P < .001$), ie, darkening of the root, interruption of the white lines, diversion of the IAN canal, and narrowing of the roots. Deflection of the roots was not statistically associated with IAN exposure ($P = .6$). For the statis-

Table 2. RADIOGRAPHIC AND CLINICAL FINDINGS AND THEIR RELATIONSHIPS TO IAN EXPOSURES AFTER M3 REMOVAL

	IAN Exposure		
Radiographic/Clincal Finding	Yes	No	Total
Darkening of the root			
Yes	17	55	72
No	7	344	351
Total, $P < .001$	24	399	423
Interruption of the white line			
Yes	18	134	152
No	6	265	271
Total, $P < .001$	24	399	423
Diversion of the canal			
Yes	10	43	53
No	14	356	370
Total, $P < .001$	24	399	423
Deflection of the root			
Yes	4	55	59
No	20	344	364
Total, $P < .6$	24	399	423
Narrowing of the root			
Yes	12	38	50
No	12	361	373
Total, $P < .001$	24	399	423
Clinician's prediction			
Exposure	19	56	75
No exposure	5	343	348
Total, $P < .001$	24	399	423

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Table 3. SENSITIVITY, SPECIFICITY, AND PREDICTOR VALUES

Predictor Variable	Sensitivity	Specificity	Positive Predictor Variable	Negative Predictor Variable	Relative Risk	*P* Value
Darkening of the root	0.71	0.86	0.24	0.98	11.8 (5.1–27.5)	.001
Interruption of the white lines	0.75	0.66	0.12	0.98	5.4 (2.2–13.2)	.001
Diversion of the IAN canal	0.42	0.89	0.19	0.96	5.0 (2.3–10.7)	.001
Deflection of the roots	0.17	0.86	0.07	0.95	1.2 (0.4–3.5)	.60
Narrowing of the root	0.50	0.91	0.14	0.97	7.5 (3.6–15.7)	.001
Clinician's prediction of nerve exposure	0.79	0.86	0.25	0.99	17.6 (6.8–45.7)	.001

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tically significant radiographic signs, the sensitivities ranged from 0.42 to 0.75, specificities ranged from 0.66 to 0.91, PPVs ranged from 0.12 to 0.24, and NPVs ranged from 0.97 to 0.99 (Table 3).

The clinician's preoperative estimate of IAN exposure was statistically associated with IAN exposure at the time of the extraction ($P < .001$; relative risk = 17.6 [6.8 to 45.7]), sensitivity = 0.79; specificity = 0.86; PPV = 0.25; NPV = 0.999).

Table 4 summarizes the relationship between the number of radiographic signs present in a radiograph and IAN exposure. As the number of signs increases, the relative risk of IAN exposure also increases ($P = .004$). Of note is that in the absence of any radiographic signs, there were no cases in which the IAN was visualized after M3 removal.

Discussion

Injury to the IAN following M3 removal is an uncommon but serious complication. Studies indicate that nerve dysfunction after M3 surgery is the third most common complication after alveolar osteitis and postoperative infections, with an approximate incidence of 0.57% to 5.3%.[10] Postoperative IAN neurosensory injuries usually resolve within a few months, but can be distressing, especially if they persist. Etiologic factors associated with nerve injury include experience of the surgeon, age of the patient, traumatic tissue manipulation, postsurgical edema, and most importantly, the anatomic proximity of the nerve to the tooth.[10]

Table 4. NUMBER OF RADIOGRAPHIC SIGNS PRESENT VERSUS IAN EXPOSURE

No. of Radiographic Signs Present	IAN Exposed	IAN Not Exposed	Relative Risk
0	0 (0%)	189 (100%)	N/A*
1	3 (2.2%)	131 (97.8%)	1
2	7 (10.4)	60 (89.6)	4.7 (1.3, 17.5)
3	10 (41.7)	14 (58.3)	18.6 (5.5, 62.70)
4	4 (44.4)	5 (55.6)	19.9 (5.2, 75.5)
5	0 (0%)	2 (100%)	N/A†
Total	24	399	

NOTE. $P < .004$.

*Risk cannot be computed because there is a 0 in 1 cell.

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The panoramic radiograph is the imaging modality most oral and maxillofacial surgeons use to view impacted M3s and to assess the risk for IAN injury.[1] Five radiographic signs have been suggested as indicative of a close relationship between M3 and the inferior alveolar nerve canal: 1) darkening of the root, 2) deflected roots, 3) narrowing of the root, 4) interruption of the white line, and 5) diversion of the IAN canal.[8] While all 5 signs were found on the radiographs during this study; only 4 were statistically significant related to IAN exposure: 1) darkening of the root, 2) narrowing of the root, 3) interruption of the white line, and 4) diversion of the IAN canal.

One of our research group's long-term goals has been to understand better the relationships between positive panoramic findings and the anatomic relationship of the IAN and M3. Most studies, aimed at evaluating the relationship between radiographic imaging and nerve position, have designated IAN nerve injury as the primary outcome variable. The absence of any positive radiographic findings provides clinically useful information because the risk of IAN injury in such cases is vanishingly low. The presence of 1 or more positive findings, however, is somewhat less useful and complicates decision-making.

As a direct consequence of the low frequency of IAN injury (<2%), the associated positive predictive value of a positive radiographic finding is low. Holding the sensitivity and specificity of the radiographic findings constant, a way to increase the positive predictive value is to increase the frequency of the observed outcome. As such, we have chosen to use a more frequent observation (ie, IAN exposure following M3 removal) as the outcome

variable in this study rather than a less frequent event (ie, IAN injury).

The findings in this study tend to be consistent with other reports regarding the association between radiographic findings and IAN injury. Our findings replicate the work of Howe and Poyton,[2] who reported that darkening of the root on a radiograph was the most reliable indication of a true relationship between M3 and the IAN. Rood and Shehab[8] found a significant relationship between diversion of the canal, narrowing of the root, nerve interruption of the white line, and nerve injury. The current study concurred with these results and established a significant relationship between these variables and IAN exposure. While Rood and Shehab[8] found a significant relationship between deflection of the roots and nerve injury, we did not find deflection of the roots to be a reliable indicator of nerve exposure ($P < .60$). This is perhaps due to the fact that while the root may be deflected, it may be deflected away from the nerve canal.

The results of this study support the hypothesis that the positive and negative predictive values of the radiographic signs as markers for anatomic intimacy between M3 and the IAN would be greater than for IAN injury alone. 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.[7] The PPVs in this study ranged from 0.07 to 0.24. The increase in the PPVs is most likely caused by the increased prevalence of the observation, IAN exposure (ie, 5.7%). Similar to the previous literature, the negative predictive values in this study approached 0.99, indicating that, in the absent positive radiographic signs, there is a minimal chance of nerve exposure.

In clinical practice, it is rare to rely on only an isolated fact or finding to make decisions. In the setting of assessing the risk of IAN injury following M3 extraction, the clinician, consciously or unconsciously, incorporates multiple radiographic findings into the decision-making process, eg, degree of root development, anatomic position of M3, overall degree of extraction difficulty, and type and number of positive radiographic signs. Although the differences may not be statistically significant, numerically, the clinician's assessment of risk had the highest positive and negative predictive values. Thus, the surgeon's overall clinical impression, based on radiographic findings, may be an important consideration when predicting IAN nerve exposure.

The results of this study confirm the clinical impression that as the number of radiographic signs increases, so does the likelihood that a nerve exposure will occur during extraction (Table 4). As such, is it important to consider both binary presence or absence of 1 radiographic sign and how many signs are present on any 1 radiograph.

Panoramic radiographic findings associated with IAN injury (ie, darkening of the root, narrowing of the root, interruption of the white line, and diversion of the IAN canal) are also statistically associated with an increased risk for IAN exposure at the time of M3 removal. Interpreting these findings, however, continues to be clinically challenging. In the setting of negative radiographic findings, the risk of IAN exposure and associated IAN injury are very low. Given positive radiographic findings, however, other imaging modalities (eg, periapical images), computerized or other forms of tomography may be indicated to ensure more accurate risk assessment, patient counseling, and decision-making.

References

1. Manpower survey of oral surgery. Part I. J Oral Surg 35(special issue A):A55-A95, 1977
2. Howe GL, Poyton HG: Prevention of damage to the inferior alveolar nerve during extraction of mandibular third molars. Br Dent J 109:355, 1960
3. Hochwald DA, Davis WH, Mortinoff JM: Modified distolingual splitting technique for removal of impacted mandibular third molars: Incidence of postoperative sequelae. Oral Surg Oral Med Oral Pathol 56:9, 1983
4. Alling CC: Dysesthesia of the lingual and inferior alveolar nerves following third molar surgery. J Oral Maxillofacial Surg 44:454, 1986
5. Wofford DT, Miller RI: Prospective study of dysesthesia following odontectomy of impacted mandibular third molars. J Oral Maxillofacial Surg 45:15, 1987
6. Bruce RA, Frederickson GC, Small GS: Age of patients and morbidity associated with mandibular third molar surgery. J Am Dent Assoc 101:240, 1980
7. Blaeser B, August MA, Kaban LB, et al: Radiographic risk factors for inferior alveolar nerve injury during third molar extraction. J Oral Maxillofac Surg 61:417, 2003
8. Rood JP, Shehab AA: The radiological predilection of inferior alveolar nerve injury during third molar surgery. Br J Oral Maxillofac Surg 28:20, 1990
9. Pell GJ, Gregory GT: Report on a ten-year study of a tooth division technique for the removal of impacted teeth. Am J Orthod 28:660, 1942
10. Miller CS, Nummikoski PV, Barnett DA, et al: Cross-sectional tomography. A diagnostic technique for determining the bucco-lingual relationship of impacted mandibular third molars and the inferior alveolar neurovascular bundle. Oral Surg Oral Med Oral Pathol 70:791, 1990
11. Rud J: Third molar surgery: Relationship of root to mandibular canal and injuries to inferior dental nerve. Tandlaegebladet 87:619, 1983
12. Leonard M: Radiographic assessment of wisdom teeth. J Irish Dent Assoc 13:37, 1967
13. Kipp DP, Goldstein BH, Weiss WW: Dysesthesia after mandibular third molar surgery: A retrospective study and analysis of 1377 surgical procedures. J Am Dent Assoc 100:185, 1980
14. Azaz B, Shteyer A, Piamenta M: Radiographic and clinical manifestations of the impacted mandibular third molars. Int J Oral Surg 5:153, 1976
15. Sisk AL, Hammer WB, Shelton DW, et al: Complications following removal of impacted third molars: The role and experience of the surgeon. J Oral Maxillofacial Surg 44:855, 1986
16. Van Gool AV, Ten Bosch JJ, Boering G: Clinical consequences of complaints and complications after removal of the mandibular third molar. Int J Oral Surg 6:29, 1977