Radiographic Assessment of Features of Impacted Mandibular Third Molars With Post-Operative Injury to the Inferior Alveolar Nerves: A Record-Based Cross-Sectional Study

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Key words: Impacted mandibular third molar, Panoramic radiograph, Inferior alveolar nerve injury

ABSTRACT

Background

Surgical removal of impacted mandibular third molars (IMTMs) is among the most common minor oral and maxillofacial surgical procedures. However, it carries the risk of complications, including injury to the inferior alveolar nerve (IAN). Panoramic radiography can predict this risk based on certain radiographic features, including root darkening, interruption of the radiopaque line of the inferior alveolar canal, canal diversion, dark and bifid apex, root deflection, narrowing of the IAN canal, and root narrowing.

Objective

To assess the prevalence and distribution of seven radiographic signs predictive of IAN injury during mandibular third molar surgery namely, root darkening, interruption of the white line, IAN canal diversion, root deflection, narrowing of the IAN canal, dark and bifid apex, and root narrowing and evaluate their correlation with clinical outcomes in adult patients.

Methods

This retrospective, cross-sectional study reviewed 258 panoramic radiographs of adult patients aged 18–60 years (120 males and 138 females) with 341 impacted mandibular third molars located in proximity to the IAN canal. Predictor variables were the seven radiographic signs listed above. The primary outcome variable was postoperative IAN injury. Data were analyzed using SPSS version 23.0. Statistical tests included ANOVA, chi-square, and correlation coefficients, with significance set at $p<0.05$. Data were presented using descriptive statistics, tables, charts, and graphs.

Results

The most frequent radiographic sign was interruption of the radiopaque superior margin of the IAN canal (n = 182, 70.5%), followed by narrowing of the IAN canal (n = 143, 55.4%) and root darkening (n = 105, 40.7%). Of the 341 IMTMs, 76 (21.4%) were surgically removed, and 13 (17.1%) of these cases resulted in IAN injury. Among them, eight had interrupted radiopaque lines, three had canal narrowing, and one each showed root deflection and root darkening.

Conclusion

The most predictive radiographic signs of IAN injury during surgical removal of IMTMs were interruption of the radiopaque canal margin, canal narrowing, and root darkening. Surgeons should carefully assess these signs preoperatively to reduce the risk of nerve injury.

INTRODUCTION

Mandibular third molars are the most commonly impacted teeth and are often associated with pathologies such as infections, inflammation, and cystic lesions.[1,2] The roots of impacted mandibular third molars (IMTMs) often lie in close proximity to the inferior alveolar canal (IAC), posing a risk of inferior alveolar nerve (IAN) injury during extraction.[3–6] The surgical removal of IMTMs is one of the most frequently performed minor procedures in oral and maxillofacial surgery. Effective and safe disimpaction depends on thorough preoperative assessment, particularly radiographic evaluation of the IMTM's relationship to the IAC.[7] The risk of IAN injury, reported to range from 0.5% to 5%,[8–10] can be reduced through careful consideration of radiographic signs and other clinical variables such as patient age, tooth morphology, bone architecture, surgeon experience, and anesthetic technique.[5]

Panoramic radiography remains the most widely used imaging modality due to its availability and broad field of view. Despite being a two-dimensional image of a three-dimensional structure—leading to possible distortions or overlaps—panoramic images can indicate potential IAN involvement through features such as root deflection, root darkening, and canal narrowing.[14,15] Cone-beam computed tomography (CBCT), though more precise in visualizing three-dimensional relationships, is less commonly used due to cost and accessibility.[16] Radiographic predictors have been reported to have a sensitivity of 66–79% and specificity of 39–86% for IAN injury.[17–19] This study assessed the prevalence and distribution of seven specific panoramic radiographic signs indicative of IAN proximity in IMTMs and evaluated their association with IAN injury after surgical removal in a Northern Nigerian population.

METHODS

Ethics: This retrospective, cross-sectional study received ethical approval from the Health Research Ethics Committee of Aminu Kano Teaching Hospital (Approval No. NHREC/28/01.2020/AKTH/EC/3904, November 2024). It adhered to the STROBE guidelines and the Declaration of Helsinki. A waiver of informed consent was granted due to the study's record-based nature.

Study Design and Setting

The study was conducted at the Oral and Maxillofacial Radiology Unit, Department of Oral Diagnostic Sciences, Aminu Kano Teaching Hospital, Kano, Nigeria, from January 1, 2021, to December 31, 2022. Panoramic radiographs (dental pantomographs) were acquired using a Planmeca ProMax digital panoramic machine and Planmeca Romexis software (version 4.3.0R).

Participants

Inclusion Criteria

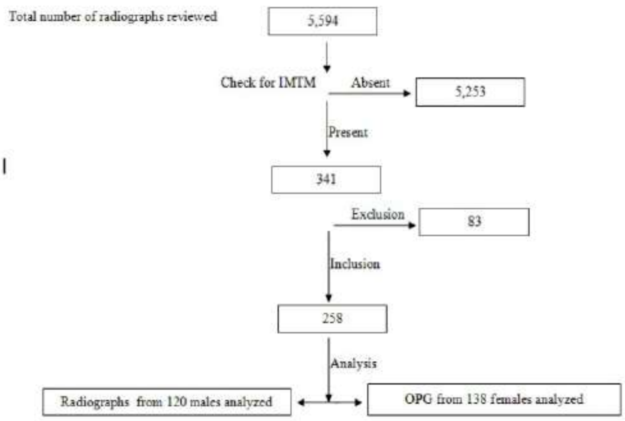
- Adults aged 18–65 years
- Presence of at least one impacted mandibular third molar in either or both quadrants
- Radiographs taken during the study period

Exclusion Criteria

- Radiographs showing jaw trauma, dentoalveolar pathologies, or craniofacial anomalies
- IMTMs with incomplete root formation
- Fully erupted mandibular third molars
- Radiographs with incomplete demographic information or poor image quality
- Radiographs taken outside the study period

Out of 5,594 radiographs reviewed, 341 images with impacted mandibular third molars were initially identified. Following application of the inclusion and exclusion criteria, 258 panoramic radiographs were selected for final analysis, as illustrated in the STROBE flow chart below:

Flow chart of participants' selection



Variables Assessed

Independent Variables

Radiographic features of impacted mandibular third molars, including:

a. Position and angulation of the impacted tooth
b. Depth of impaction
c. Radiographic risk signs
d. Proximity of the IMTM to the inferior alveolar canal (IAC)

Dependent/Outcome Variable

Post-operative injury to the inferior alveolar nerve (IAN), defined as numbness on the ipsilateral lower lip compared to the contralateral side. This was measured by the presence and duration of sensory impairment following mandibular third molar extraction.

Data Sources and Management

Dental pantomographs and medical records of patients were used to extract age, sex, and the required radiographic variables.

Sample Size Justification

As a retrospective record-based study over a defined period, sample size calculation was not required. All eligible cases within the study period that met the inclusion criteria were included.

Image Analysis and Bias Control

Two senior residents in Oral and Maxillofacial Radiology independently assessed the dental pantomographs under the supervision of a consultant. Both examiners were blinded to clinical and demographic data to minimize selection bias and ensure consistent radiographic interpretation. Assessments were made for each mandibular quadrant (right and left). A third molar was considered to show a radiographic risk when there was an intimate relationship between its roots and the IAC. Discrepant assessments were resolved through consensus discussions. Inter-observer agreement was evaluated using kappa statistics.[20]

Impaction Patterns of Mandibular Third Molars

The patterns of impaction were analyzed using two main classification systems: Winter's and Pell & Gregory's.

Winter's Classification[21]: Assessed the angulation of impaction based on the angle formed between the long axes of the second and third molars. Measurements were taken using the Planmeca Romexis 4.3.0R software. Classification was as follows:

- Mesioangular: 11°–79°
- Horizontal: 80°–100°
- Vertical: 10° to −10°
- Distoangular: −11° to −79°
- Others: 111° to −80°, including rare patterns like mesio-inverted, disto-inverted, and disto-horizontal[22]
- Buccolingual: Indicated by crown and root superimposition. Figures 1–3 illustrate these classifications.

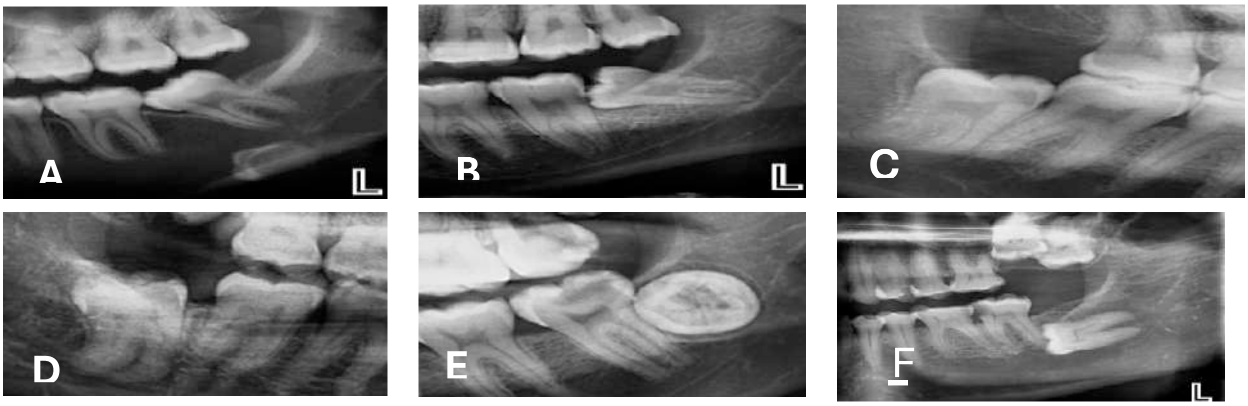


Figure 1: Cropped images of panoramic radiographs demonstrating Winter's Classification System of impaction of mandibular third molar showing: (a) mesioangular impaction, (b) partially bony horizontal impaction, (c) vertical impaction, (d) distoangular impaction, (e) buccolingual impaction, (f) fully intrabony horizontal impaction.[23]

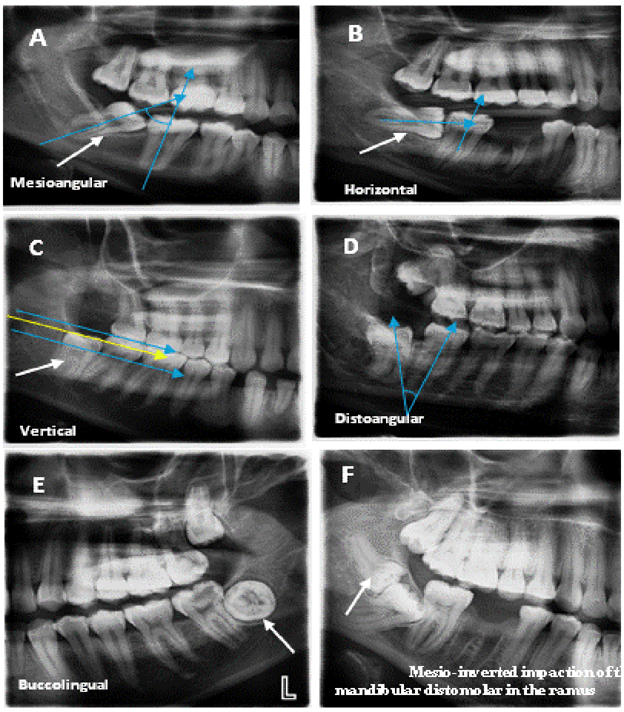


Figure 2: Different angulations of impacted mandibular third molar assessment [Winter's classification (A-F)][23]

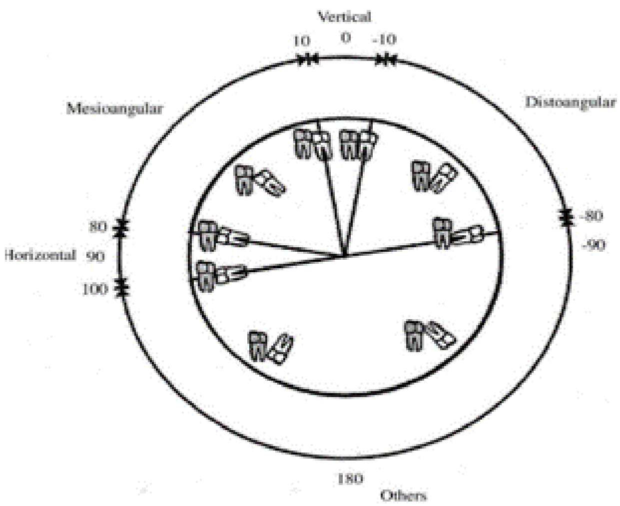


Figure 3: Graphic demonstrating Quek's classification ofangulation of impaction, being mesioangular (11 – 79 degrees), horizontal (80 – 100 degrees), distoangular (11 -79 degrees),vertical (10 to -10 degrees), and others (-111 to -80 degrees).
[Graphic reproduced with permission from Quek et al.[22]]

Depth of Impaction

This was considered in relation to the alveolar bone margin and the cementoenamel junction of the impacted tooth. The classification of the depth of third molar impaction was adapted from Pell and Gregory classification24 and was categorized into: Level A: Not buried in bone; Level B: Partially buried in bone if any part of CEJ was lower than bone level; Level C: Completely buried in bone [Figure 4].

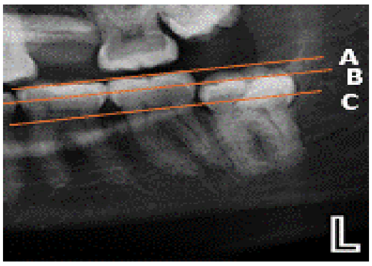


Figure 4: The classification of third molar impaction adapted from Pell and Gregory Classification [23]

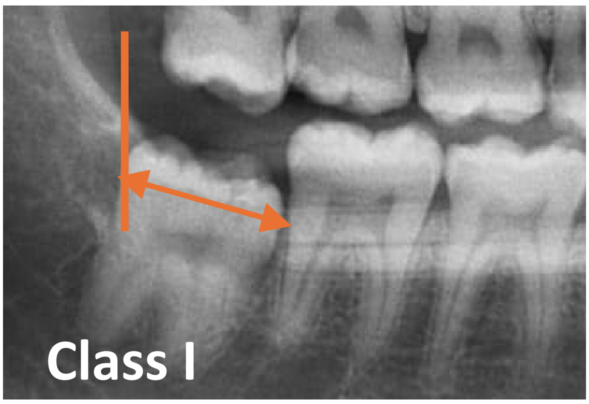
Mandibular Ramus Relationship

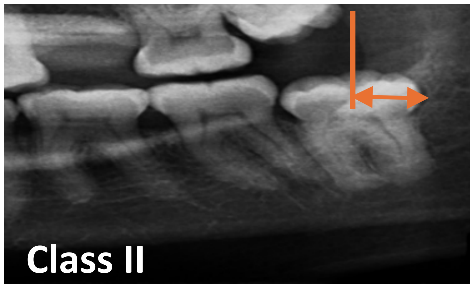
The relationship between the impacted mandibular third molar and the mandibular ramus was evaluated using the Pell and Gregory classification system.[24] This model assesses the position of the anterior border of the ascending ramus in relation to the distal surface of the crown of the mandibular third molar. Each impacted tooth was categorized as follows:

Class I: The entire crown is located anterior to the anterior border of the ramus

Class II: The anterior border of the ramus covers approximately half of the crown

Class III: The crown is completely embedded within the ramus [Figure 5]





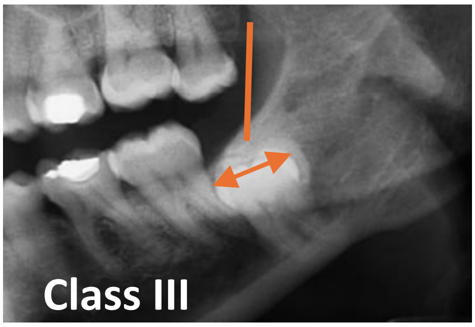


Figure 5: Illustrates the relationship between the impacted mandibular third molar (IMTM) and the mandibular ramus:
Class I: The crown is positioned anterior to the anterior border of the ramus
Class II: Approximately half of the crown is covered by the anterior border of the ramus
Class III: The crown is completely covered by the anterior border of the ramus

Relationship between the Inferior Alveolar Nerve (IAN) and the Impacted Mandibular Third Molar (IMTM)

The anatomical relationship between the roots of the IMTM and the inferior alveolar canal (IAC), which houses the IAN, was assessed using dental pantomographs. This evaluation was based on the seven radiographic risk signs described by Rood and Shehab[25]: [Figures 6, 7 and Table 1]

1. Darkening of the root of the IMTM
2. Diversion of the IAC
3. Interruption of the superior radio-opaque cortical line of the IAC
4. Deflection of the roots
5. Narrowing of the IAC
6. Narrowing of the IMTM roots
7. Dark and bifid apex

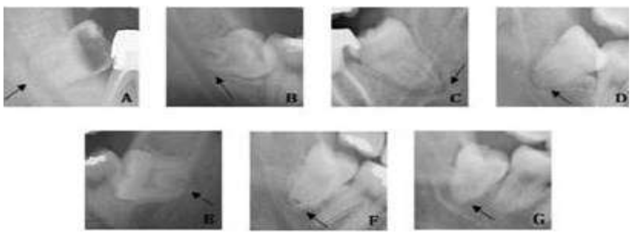


Figure 6. (A) root darkening, (B) root deflection, (C) root narrowing, (D) dark and bifid apex, (E) loss of white line, (F) inferior alveolar nerve (IAN) narrowing, and (G) IAN diversion. [Rood and Shehab classification of radiographic signs.

[25]]

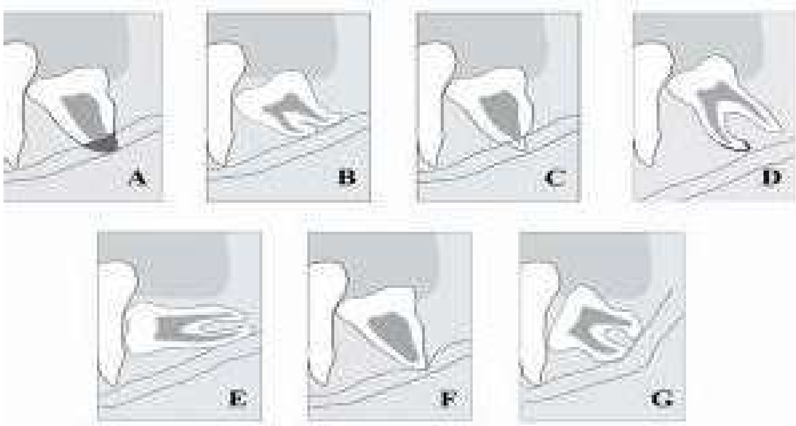


Figure 7: Panoramic view. Signs: (**A**) root darkening, (**B**) root deflection, (**C**) root narrowing, (**D**) dark line in apex, (**E**) Interruption of the superior radio-opaque cortical line of the IAC, (**F**) inferior alveolar nerve (IAN) narrowing, and (**G**) IAN diversion. [Adapted from Kim et al [23]]

Table 1: Radiographic signs of risky relationships between MTM root and the binferior alveolar canal

RADIOGRAPHIC SIGNS	DESCRIPTIONS
1. Darkening of the root of IMTM	Radiolucency of the mandibular third root area, where mandibular third root and mandibular canal are superimposed
2. Diversion of the IAC	Change in the direction of the mandibular canal as mandibular third molar root impinges on the IAC
3. Interruption of the superior radio-opaque cortical line of the IAC	Absence of continuity of the superior radiopaque cortical line of the IAC
4. Deflection of the roots	Dilaceration of the root morphology of mandibular third, where IAC is contact or superimposed to it
5. Narrowing of the IAC	Narrowing of the IAC diameter where the canal and mandibular third root are contact or superimposed
6. Narrowing of the roots of the IMTM	Narrowing of the mandibular third root, where the IAC and mandibular third root are contact or superimposed
7. Dark and bifid apex	Bifid and darkening of the mandibular third root, where IAC is superimposed to it

Proximity of the IMTM Root to the IAC

The proximity of the impacted mandibular third molar (IMTM) root to the inferior alveolar canal (IAC) was classified into three categories:

- Close: ≤1 mm distance between the IMTM root and the superior radiopaque cortical line of the IAC
- In contact: Direct contact between the IMTM root and the superior radiopaque cortical line of the IAC
- Overlapping: Superimposition of the IMTM root over the IAC

Each patient's medical record was reviewed to identify any complaints of postoperative nerve injury specifically, numbness of the ipsilateral lower lip during the one-week postoperative follow-up review.

Data Analysis

Data were analyzed using SPSS for Windows, version 23.0 (IBM, Chicago, IL, USA). Descriptive statistics were reported as frequencies and percentages. Chi-square (χ^2) tests were conducted, with the confidence interval set at 95% and the significance level at $p \leq 0.05$.

RESULTS

Examiner Agreement

The overall inter-examiner agreement for the assessment of panoramic radiographs was good, with kappa scores ranging from 0.64 (right mandible) to 0.75 (left mandible).

Sociodemographic Characteristics

The age range of participants was 18 to 65 years, with a mean age (± SD) of 31.75 ± 8.33 years. There were 120 (46.5%) male and 138 (53.5%) female radiographs evaluated [Table 2]. Participants were grouped into six age categories, with the highest proportion (38.8%) falling within the 30–39 years age group [Table 2].

Prevalence and Pattern of Impactions

The prevalence of impacted mandibular third molars was 6.10%, with the highest occurrence in the 20-29 years age group and the lowest in those over 50 years. Female participants had a higher frequency of impactions than males.

- Based on Winter's classification, mesioangular impaction was the most common (n = 148; 43.4%), while distoangular impaction was the least frequent.
- Based on Pell and Gregory's classification
- For depth of impaction, Class C was most common (19.1%) and Class A was the least common (14.7%).
- For ramus relationship, Class II was the most frequent (82.7%), followed by Class I, while Class III was the least frequent (7.2%). [Tables 2 and 3]

Table 2: Sociodemographic factors of participants (n= 258)

FACTORS	FREQUENCY	PERCENTAGE	MEAN±SD
AGE			31.75±8.33
<20	11	4.2%	
20-29	99	38.4%	
30-39	100	38.8%	
40-49	40	15.5%	
50-59	7	2.7%	
≥60	1	0.4%	
SEX			
Female	138	53.5%	
Male	120	46.5%	

Table 3: Distribution of the different classifications of IMTM

WINTER S (Freq/%)	PELL AND GREGORY (Freq/%)	PELL AND GREGORY (Freq/%)
MA - 148 (43.4%)	A - 50 (14.7%)	I - 29 (8.5%)
DA - 6 (1.8%)	B - 62 (18.2%)	II - 282 (82.7%)
V - 85 (24.9%)	C - 65 (19.1%)	III – 26 (7.2%)
H - 100 (29.3%)		
*Others - 2 (0.6%)		

*Mesioinverted, Distoinverted and Disto-horizontal (MA-mesioangular; DA - Distoangular; V - Vertical; H- Horizontal)

Proximity of Impacted Mandibular Third Molar Roots to the Inferior Alveolar Canal (Predictor of IAN Injury)

Interruption of the superior radiopaque margin of the inferior alveolar canal (IAC) was the most frequently observed radiographic risk sign, occurring in 219 cases (64.2%). The least observed was the presence of dark and bifid root apices. Other radiographic signs appeared at varying frequencies. A majority of the IMTM roots were either in direct contact with the IAC (n = 229; 67.1%) or overlapping it (n = 104; 30.5%) as shown in Table 4.

There was no statistically significant association between inferior alveolar nerve (IAN) injury and any of the radiographic risk signs observed on panoramic radiography ($p > 0.05$). Further regression analysis revealed that all coefficients were small in magnitude. Most coefficients were negative, suggesting a slight (non-significant) protective effect against nerve injury. Two features root deflection ($B = 0.016$) and root narrowing ($B = 0.014$)—showed small, positive, but non-significant associations with IAN injury ($p > 0.05$) [Table 5].

Table 4: Distribution of the predictor variables, proximity of IMTM roots to the IAC and injury to the IAN

VARIABLES	FREQUENCY	PERCENTAGE
RADIOGRAPHIC RISK SIGNS		
Root darkening	125	36.6%
Diversion of the IAC	94	27.6%
Interruption of the radiopaque white line	219	64.2%
Deflection of the root	79	23.2%
Narrowing of the IAC	169	49.6%
Dark & Bifid apex	1	0.3%
Narrowing of the root	41	12.0%
PROXIMITY BETWEEN IMTM AND IAC		
Close	25	7.3%
Contact	229	67.1%
Overlap	104	30.5%
INJURY TO IAN		
With injury to IAN (Numbness)	13	17.1%
Without injury to IAN	63	82.9%

Table 5: Bivariate correlation between the radiographic risk signs (predictor) and the IAN injury (outcome) variables

Radiographic risk signs	Injury to IAN		Total	p Value
	Yes	No		
Root darkening	4 (30.8%)	121 (36.9%)	125	>0.05*
Diversion of the IAC	2 (15.4%)	92 (28.0%)	94	
Interruption of the radiopaque white line	9 (69.2%)	210 (64.0%)	219	
Deflection of the root	4 (30.8%)	75 (22.9%)	79	
Narrowing of the IAC	7 (53.8%)	165 (50.3%)	172	
Dark & Bifid apex	0 (0.0%)	1 (0.3%)	1	
Narrowing of the root	2 (15.4%)	39 (11.9%)	41	

*Statistical insignificance p>0.05, Pearson's Chi-square test

Odds of IAN Injury

Our study found the following odds ratios:

1. Diversion of the IAC – OR = 0.426 (95% CI: 0.093–1.939)
2. Narrowing of the IAC – OR = 0.982
3. Root Darkening – OR = 0.958 (95% CI: 0.314–2.926)
4. Interruption of the White Line – OR = 1.003 (95% CI: 0.328–3.062)
5. Narrowing of the Root – OR = 1.231(95% CI: 0.265–5.706)
6. Deflection of the Root – OR = 1.344 (95% CI: 0.410–4.408). CIs include one and p > 0.05 hence not statistically significant.

DISCUSSION

Findings:

Pre-operative radiographic evaluation of the precise relationship between the roots of the impacted mandibular third molar and IAN canal could be of assistance in predicting risk of IAN injury and eventually giving surgeons the clues to avoiding post-surgical sensory neuropathy.[27] Panoramic radiographic assessment is the most commonly used pre-operative imaging modality in evaluating mandibular third molar impactions and estimating the risk of IAN damage. It is a more objective assessment tool compared to periapical radiographs. This is because the head position is fixed during the image capturing with operator bias being less likely to occur.[26, 28]

[31] Several authors have evaluated the reliability of panoramic radiography over the more advanced radiographic modalities such as CBCT in predicting injury to the IAN. Controversial results were reported where few researchers claim that the advanced imaging techniques have higher accuracy in the prediction of IAN exposure.[32–34] whereas others reported no statistical difference between the two imaging methods.[12,33,35,36] We routinely perform digital panoramic radiography as an initial radiographic assessment for all patients with IMTM. However, advanced radiography is recommended when radiographic signs appear in panoramic radiographs that show a direct anatomical relationship between the third molar and canal.[37]

Despite the prevalence figures shown in Table 4, there was a different message from the odds ratios. The odds ratios in the risk estimates evaluate how likely IAN injury is to occur in the presence of each radiographic sign compared to its absence, whereas Table 4 shows the following frequency (prevalence) of the radiographic signs. This means some signs are common but not necessarily predictive. Since high prevalence does not equate high risk, a radiographic sign may be common (like interruption of the white line) but if it happens to appear in both injured and uninjured cases equally, it will not show significance in odds ratios. Again, the small number of IAN injury cases (n = 13) reduces statistical power coupled with wide confidence intervals and insignificant p-values reflecting low precision of the ORs. Most ORs hover around 1, indicating no increased or decreased odds of injury. The commonest radiographic risk sign associated with IAN injury in our study was the interruption of the radiopaque upper line, which is at variance with several studies.[15,25,28,29] The narrowing of the IAN canal was our second commonest radiographic sign associated with IAN injury which though not in full agreement, is close to the findings of Elkhateeb and Awad.[35] They identified the interruption of the IAN canal line or darkening of the roots in combination with diversion of the IAC as high risk indicators of IAN injury. Our findings are however at variance with those of Monaco and co-workers who reported narrowing of the IAN canal as the most frequent associated radiographic factor.[38] The narrowing of the IAN canal was the third commonest radiographic factor reported by Elkhateeb and Awad.[35]

The literature is replete with significant disagreement in the relative importance of the various radiographic predictors of IAN injury. These variances warrant further evaluation in larger studies. For instance, our third commonest radiographic sign was darkening of the roots of IMTM, which corroborates several previous studies[26,32,39,40] affirming the darkening of roots as the most associated sign of the actual relationship between the roots of IMTMs and IAN canal in terms of contact. Our findings are however at variance with other studies which reported the darkening of IMTM roots as the second most associated radiographic sign for IAN injury.[27,35] Further controversy is clearly reflected in the occurrence of the diversion of canal being our fourth commonest radiographic predictor of IAN damage but the commonest radiographic risk factor reported by several studies.[15,25,28,29] The controversy might be related to differences in the interpretation of prevalence/predictor factors. Many studies reported frequencies of radiographic signs in association with IAN injury without reporting the odds of the occurrences.[15,17,35,36]

Multiple radiographic risk factors and risk of IAN injury is an important risk predictor. Our study found several patterns of the proximity of the roots of the IMTMs to the IAN canal as an important predictor of IAN injury with the contact of IMTM roots being the most prevalent (67.1%), corroborating previous studies.[26,41] Unlike the findings of Nakamori et al.,[42] our present study found that none of the reported radiographic risk factors was noted to be absent in any of the studied radiographs. This is in agreement with several previous studies that linked the presence of multiple radiographic risk factors with the increased likelihood of IAN nerve injury.[12,35,41,43,44]

While all the signs were present in our study, we found no statistical significance between panoramic radiographic risk and injury to the IAN. This is inconsistent with the findings of other workers who reported statistical significance of interruption of radiopaque lines, diversion of IAN and narrowing of the IAC. Others included darkening of the root, narrowing of the root, interruption of the radiopaque lines, and diversion of the canal respectively with injury to the IAN.[17,41] However, our present study is in part consistent with the study by Huang et al.[41] who reported no statistical significance in darkening of the roots and deflection of the root with IAN injury. Other workers used 3-dimensional computed tomogram to confirm the value of panoramic radiograph to predict physical contact between IMTM roots and IAC.[45] The interruption of radiopaque upper cortical line of the IAC was our commonest radiographic risk factor for dental surgeons to consider prior to the surgical extraction of IMTM in close proximity to the IAN canal. The reasons of the wide variance between our findings and previous studies are obvious but the reasons are unclear. Larger studies may help address the wide discrepancy among the findings.

Implications

Oral and maxillofacial surgeons should remember to make digital panoramic radiography a routine investigation for all patients with IMTM requiring surgical disimpaction.

Oral and maxillofacial surgeons should particularly look out for the interruption of radiopaque upper cortical line of the IAC being the most common radiographic risk factor for IAN injury in our study. A sign like interruption of the radiopaque line though common, is not statistically predictive in this dataset. It is the commonest sign in Table 4 but failed to show up as a significant predictor in the odds ratio analysis.

The phrase "predictor of IAN injury" should be interpreted with caution in studies that lack the statistical rigor to make such declarations specifically studies that do not report effect sizes like odds ratios and corresponding confidence intervals.

Trade-Offs (Limitations)

Though our study was strong on methods with strong inter-observer agreement of 0.64 and 0.75, which we believed minimized bias, the small sample size is a limitation.

A single-center study is prone to the risk of selection bias.

Take-Home (Conclusion)

Deflection of the root was the strongest predictor of IAN injury in this study.

Panoramic radiography stands out as a cost-effective preliminary diagnostic imaging tool to predict IAN injury.

The interruption of radiopaque upper cortical line of the IAC was the commonest radiographic sign but deflection of the root was the strongest predictor of IAN injury in this study, though it did not attain statistical significance (OR = 1.344, $p > 0.05$).

Expectations for Future Research

Future studies in our environment should consider using CBCT.

The confusion between reported frequencies and actual risk should be reported in subsequent studies to avoid the potential risk of confusing commonest occurrences with highest risk.

Recommendations

We recommend larger studies to confirm or refute the findings of the present study probably by working with larger data and by using an advanced three-dimensional radiographic imaging modality (CBCT) with the capability to show three-dimensional relationships between anatomical structures and with reduced radiation vulnerability.

Conflict of interest:

The authors have declared no conflict of interest in this study.

Funding:

None

Acknowledgement:

We thank all the technicians working in the Oral and Maxillofacial Radiology Unit of Oral Diagnostic Sciences Department, Aminu Kano Teaching Hospital who assisted during the data collection process.

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