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ORIGINAL ARTICLE

Objectivity and reliability of panoramic radiographic signs of intimate relationship between impacted mandibular third molar and inferior alveolar nerve

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Abstract
Introduction The results of prior studies assessing the accuracy of panoramic radiographic signs of intimate relationship between inferior alveolar nerve (IAN) and impacted molars are controversial. This may be partly due to inadequate objectivity and reliability of these radiographic signs, which is evaluated in the present study.
Materials and methods Three hundred radiographs in which impacted third molar reached the superior border of the inferior alveolar canal or was superimposed by the canal were evaluated by three examiners independently, twice 3 months apart. Inter- and intra-examiner agreements were analyzed using kappa statistics.
Results The inter-examiner agreement for all radiographic signs was poor ($k<0.2$). The intra-examiner agreement for radiographic signs 2, 3, and 6 was poor with mean kappa values of 0.08, 0.00, and 0.09, respectively. Concerning the radiographic signs 4, 5, 7, and 8, the intra-examiner agreement was moderate with mean kappa values of 0.54, 0.49, 0.44, and 0.57, respectively. The mean kappa coefficient for the radiographic sign 1 yielded a good agreement ($k=0.65$).
Conclusions In the present study, the examiners were unable to reliably assess radiographic signs of intimate relationship between IAN and third molar, indicating that panoramic images should not be relied upon for preoperative prediction of IAN injury.

Keywords Inferior alveolar nerve · Third molar · Panoramic radiography · Reliability

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Introduction

The removal of impacted mandibular third molars is one of the most commonly performed surgical procedures. A well-recognized serious complication that may occur during this operation is injury to the inferior alveolar nerve. Previous studies reported that the incidence of injury to the inferior alveolar nerve (IAN) following third molar surgery may vary from 0.5 to 8 % [1–3]. In most instances, nerve injuries are caused by surgical negligence or carelessness such as injudicious instrumentation or elevation, although sometimes the anatomic position of the tooth makes it inevitable despite the best judgment and surgical technique.

Panoramic radiography is the most commonly used imaging technique to assess the relationship of the inferior alveolar canal (IAC) to the third molar roots. According to the literature, the following panoramic radiographic signs indicate that the impacted third molar is intimately associated with the IAC: darkening of the root, dark and bifid apex, narrowing of the canal, interruption of the white line of the canal, diversion of the path of the canal, deflected roots, and narrowing of the roots [4–7]. The diagnostic accuracy of these radiographic landmarks to predict IAN damage during impacted tooth surgery has been investigated by several authors previously. Some of the earlier studies suggested that panoramic images were accurate in prediction of intimate relationship between IAN and impacted

third molar [2, 7, 8], but other studies found that the panoramic radiography was not sufficiently reliable to diagnose at-risk patients [4, 5, 9]. Wide ranges of sensitivity (14.6 to 75 %), specificity (39 to 97 %), and positive and negative predictive values (3 to 24 % and 97 to 99 %, respectively) for the panoramic radiographic signs of IAN damage were reported in previous investigations [2, 4, 10, 11].

Discrepancies in the findings of prior studies may be due to several factors, including differences in sample size, methodology of studies, and assessment method of nerve injury. Another possible explanation for this confliction that has not been thoroughly evaluated in the published literature is inconsistency and variability in assessing panoramic radiographic predictors of nerve injury. Assessment of these radiographic signs relies on some degree of subjective interpretation by observers. If the clinicians who evaluate these radiographic signs do not agree on the interpretation, the results will be of little clinical use [12]. Although some of the previous studies that have evaluated the sensitivity and specificity of panoramic radiographic signs, also presented a brief report of the level of inter-observer and intra-observer agreement, it was confined only to a few of the radiographic landmarks and was based on a small sample size while it is proven that measuring the level of inter-observer and intra-observer agreement is sensitive to sample size [5, 13–15].

The aim of the present study was to evaluate and compare the objectivity and reliability of various panoramic radiographic signs of intimate relationship between mandibular third molar and IAN.

Material and methods

The protocol of this study was approved by our institutional review board.

The clinical records of 2,630 patients who underwent impacted mandibular third molar surgery by the senior author between April 2005 and November 2012 and had a preoperative panoramic radiography were investigated. Of them, 300 high-quality radiographs in which the impacted third molar reached the superior border of the IAC or was superimposed by the canal were included in the study.

The exclusion criteria for this study were:

1. Previous surgery, infection, or fracture of the mandible
2. Congenital or developmental anomaly of the mandible
3. Panoramic images that their quality was not sufficiently high
4. No relationship between tooth and IAC in vertical plane
5. Pathologic lesion around the impacted tooth

The 300 panoramic images were assigned a number for identification purposes and evaluated by three of the four authors independently: examiner A (a board-certified oral and maxillofacial surgeon with 17 years of experience), examiner B (a board-certified oral and maxillofacial radiologist with 5 years of experience), and examiner C (a board-certified oral and maxillofacial surgeon with 2 years of experience). Before starting the study, the three examiners attended a session to review and discuss the typical panoramic radiographic risk factors of nerve injury to reach a consensus. The radiographic signs evaluated in this study were according to the criteria presented by Rood and Shehab [8] and included the following:

Sign 1. Darkening of the root: impingement of the IAC on the tooth root and loss of the root density (Fig. 1a).
Sign 2. Narrowing of the root: narrowing of the tooth root where the canal crosses it (Fig. 1b).
Sign 3. Dark and bifid apex: crossing of the root apex by IAC and double periodontal membrane shadowing of the bifid apex (Fig. 1c).
Sign 4. Interruption of the white line(s) of the canal: disappearance of the white line immediately before it reaches the tooth structure (Fig. 1d).
Sign 5. Narrowing of the canal: when the canal crosses the impacted tooth, there is a reduction of its diameter (Fig. 1e).
Sign 6. Deflection of the root: abrupt deviation of the root, when it reaches the IAC (Fig. 1f).
Sign 7. Diversion of the canal: when the canal crosses the impacted tooth, it changes its direction (Fig. 1g).
Sign 8. Contact of the root with IAC or superimposition of these structures in the absence of any of the radiographic signs 1 to 7.

After 3 months, half of the images (150 images) were randomly selected and assigned a new identification number and re-evaluated by each examiner. The selection of radiographs and assignment of the numbers were performed by an independent person who was blind to the study design. The examiners evaluated the panoramic images and recorded their interpretation in a data collection sheet.

Data analysis was performed with SPSS 16.0 software (SPSS inc., Chicago, IL, USA). The intra- and inter-examiner agreements were analyzed, and the values for the actual (observed) agreement, the chance agreement, and the kappa (k) coefficient were calculated using k statistics. In this study, the level of statistical significance was set at $P<.05$, and for interpretation of the k statistics, Altman's classification was used [16]. This classification is presented in Table 1.

Results

Of 2,630 panoramic radiographs investigated in this study, only 300 radiographs (11.4 %) showed that the root of the impacted tooth reached the superior border of the IAC or was

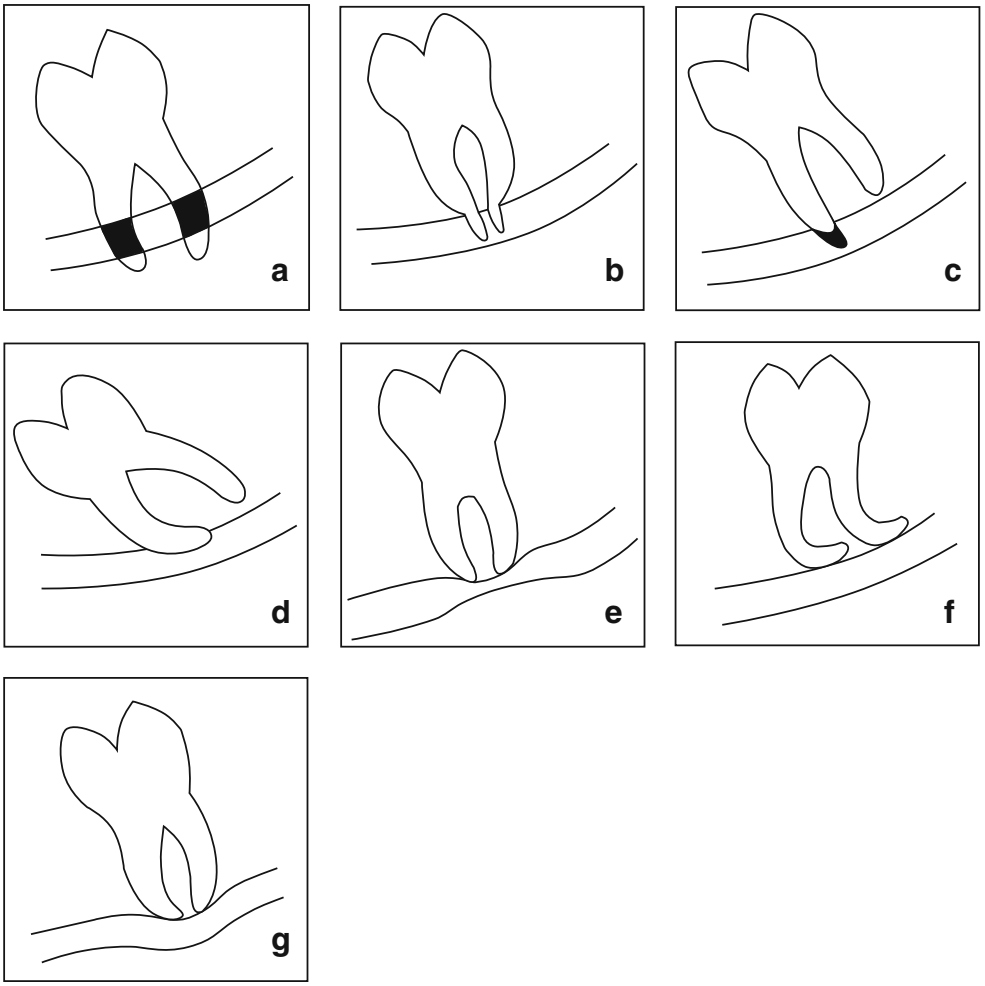

Fig. 1 Schematic drawings of the panoramic radiographic risk factors of IAN injury during mandibular third molar surgery. **a** Darkening of the root. **b** Narrowing of the root. **c** Dark and bifid apex. **d** Interruption of the white line of the canal. **e** Narrowing of the canal. **f** Deflection of the root. **g** Diversion of the canal

superimposed by the canal and were selected to be evaluated by the examiners.

Assessment of the inter-examiner agreement showed that the *k* value for all of the radiographic signs of IAN injury was less than 0.2, indicating a poor agreement between examiners (Table 2).

With regard to intra-examiner agreement, we found a considerable variability, not only among the three observers but also between radiographic signs being examined (Table 3). The intra-examiner agreement in assessing radiographic signs 2, 3, and 6 was poor with mean *k* values of 0.08, 0.00, and 0.09, respectively. Concerning the radiographic signs 4, 5, 7, and 8, the intra-examiner agreement was moderate with mean *k* values of 0.54, 0.49, 0.44, and 0.57, respectively. The mean *k* coefficient for the radiographic signs 1 yielded a good agreement (k=0.65). The overall intra-examiner agreement in assessment of the eight radiographic signs was moderate for examiner A (k=0.42) and fair for examiners B (k=0.38) and C (k=0.27).

Table 1 Interpretation of the kappa statistics according to Altman's classification

Scale	Interpretation
0.81–1.00	Very good agreement
0.61–0.80	Good agreement
0.41–0.60	Moderate agreement
0.21–0.40	Fair agreement
<0.2	Poor agreement

Discussion

Multiple prior studies have evaluated the sensitivity and specificity of various panoramic radiographic signs that predict IAN injury during mandibular impacted tooth surgery, but their results were inconsistent. Some investigations have shown that panoramic images did not posses predictive ability to determine the anatomic relationship between IAN and the third molar [5, 17, 18]. In a study by Gomes et al., changes to the IAN were found, even in the lack of contact of the tooth roots with the mandibular canal, and it was concluded that only with computed tomography it would be possible to determine the true relationship between the impacted tooth root and the IAC [4]. However, Roeder et al. demonstrated

Table 2 Inter-examiner agreement and kappa (k) values for radiographic signs of nerve injury

Comparison	Observed agreement (%)	Chance agreement (%)	k coefficient
Inter-examiner rating for sign 1			
A1 vs. B1	73	64	0.27
A1 vs. C1	66	66	0.01
B1 vs. C1	63	56	0.16
Mean	67.3	62	0.15
Inter-examiner rating for sign 2			
A1 vs. B1	96	96	0.00
A1 vs. C1	97	97	0.20
B1 vs. C1	99	99	0.01
Mean	97.3	97.3	0.07
Inter-examiner rating for sign 3			
A1 vs. B1	98	98	0.00
A1 vs. C1	97	97	0.00
B1 vs. C1	99	99	0.00
Mean	98	98	0.00
Inter-examiner rating for sign 4			
A1 vs. B1	66	53	0.26
A1 vs. C1	43	45	0.00
B1 vs. C1	61	48	0.24
Mean	56.7	48.7	0.17
Inter-examiner rating for sign 5			
A1 vs. B1	85	82	0.19
A1 vs. C1	95	95	0.00
B1 vs. C1	84	84	0.03
Mean	88	87	0.07
Inter-examiner rating for sign 6			
A1 vs. B1	96	95	0.13
A1 vs. C1	97	97	0.00
B1 vs. C1	96	96	0.02
Mean	96.3	94.3	0.05
Inter-examiner rating for sign 7			
A1 vs. B1	92	91	0.19
A1 vs. C1	98	98	0.01
B1 vs. C1	91	91	0.01
Mean	93.7	93.3	0.07
Inter-examiner rating for sign 8			
A1 vs. B1	63	49	0.27
A1 vs. C1	51	49	0.03
B1 vs. C1	73	65	0.25
Mean	62.3	54.3	0.18

A1 first observation of the observer A, *B1* first observation of the observer B, *C1* first observation of the observer C

Table 3 Intra-examiner agreement and kappa (k) values for radiographic signs of nerve injury

Comparison	Observed agreement (%)	Chance agreement (%)	k coefficient
Intra-examiner rating for sign 1			
A1 vs. A2	98	84	0.88
B1 vs. B2	81	57	0.56
C1 vs. C2	80	59	0.52
Mean	86.3	66.7	0.65
Intra-examiner rating for sign 2			
A1 vs. A2	96	95	0.24
B1 vs. B2	99	99	0.00
C1 vs. C2	99	99	0.00
Mean	98	97.7	0.08
Intra-examiner rating for sign 3			
A1 vs. A2	99	99	0.01
B1 vs. B2	99	99	0.00
C1 vs. C2	99	99	0.00
Mean	99	99	0.00
Intra-examiner rating for sign 4			
A1 vs. A2	82	60	0.55
B1 vs. B2	65	46	0.35
C1 vs. C2	85	50	0.71
Mean	77.3	52	0.54
Intra-examiner rating for sign 5			
A1 vs. A2	97	92	0.66
B1 vs. B2	87	72	0.54
C1 vs. C2	97	95	0.27
Mean	93.7	86.3	0.49
Intra-examiner rating for sign 6			
A1 vs. A2	99	99	0.00
B1 vs. B2	97	95	0.27
C1 vs. C2	97	97	0.00
Mean	97.7	97	0.09
Intra-examiner rating for sign 7			
A1 vs. A2	99	97	0.50
B1 vs. B2	97	85	0.82
C1 vs. C2	99	99	0.00
Mean	98.3	93.7	0.44
Intra-examiner rating for sign 8			
A1 vs. A2	77	50	0.55
B1 vs. B2	87	75	0.51
C1 vs. C2	83	54	0.64
Mean	82.3	59.7	0.57

A1 first observation of the observer A, *A2* second observation of the observer A, *B1* first observation of the observer B, etc.

that for proving the non-inferiority of panoramic radiography compared with cone beam computed tomography in predicting IAN injury, studies with very large sample sizes were required [19]. By contrast, several studies showed a significant association between panoramic radiographic signs and IAN injury [7, 18, 20, 21].

The conflicting results of previous investigations may be due to various factors including differences in sample size,

methodological differences between various studies, and different methods used to detect IAN exposure or damage. Inconsistency and variability in assessing panoramic radiographic signs of impacted tooth—IAN intimate relationship is another possible explanation for the conflicting results of previous studies. Before various panoramic radiographic predictors of nerve injury can be used for diagnostic or prognostic purposes, the objectivity and reliability of assessing these radiographic signs should be measured; an issue that has not been thoroughly evaluated in the literature.

In the present study, assessment of the inter-examiner reliability revealed a poor agreement among examiners in interpretation of the radiographic signs. The mean *k* coefficient for each of the radiographic signs was less than 0.2.

In this investigation, the intra-examiner agreement was poor for radiographic signs 2, 3, and 6 (narrowing of the root, dark and bifid apex, and deflection of the root, respectively), moderate for the radiographic signs 4, 5, 7, and 8 (interruption of the white line of the canal, narrowing of the canal, diversion of the canal, and absence of the radiographic signs 1 to 7, respectively), and good for radiographic sign 1 (darkening of the root).

An explanation for the poor inter-examiner and intra-examiner agreement observed in present study may be the drawbacks inherent in the panoramic radiography. The limited accuracy of panoramic radiography in determining the relationship between the impacted tooth and the IAN may be partly due to two-dimentional nature of the conventional images and the anatomic position of the mandibular canal, which is reported to be either buccally or lingually to the tooth roots in most cases [22]. Panoramic images have various degrees of distortion and magnification; lingually positioned structures are projected upward, and the IAC is usually positioned at the periphery of the focal through [4, 5]. Furthermore, because of factors such as the degree of mineralization of the mandible, the unusual position and angulation of the impacted tooth, and the presence of other radiolucencies in the area, evaluation of the location and morphology of the IAC and its relationship with impacted tooth may be more complicated. For example, several studies reported that darkening of the root was strongly suggestive of grooving and thinning of the root by the IAC [13, 23], whereas some other studies demonstrated that this radiographic sign represented lingual cortical thinning or perforation rather than grooving of the tooth root [15, 24].

In current study, the value for intra-examiner agreement was greater than that of inter-examiner agreement. This finding suggested that the examiners had some measure of self-consistency that did not extend to an agreement with each other. It is possible that despite attending a session to review the radiographic signs and reach a consensus before the study, different interpretations were made by the examiners for a radiographic sign. Poor intra-examiner agreement in assessing signs 2, 3, and 6 may be explained by the fact that *k* may not be reliable for rare observations. *k* is affected by prevalence of the finding under consideration, and for rare findings, very low values of *k* may not necessarily reflect low rates of overall agreement [12].

In the present study, the overall *k* values for the agreement between the first and second observations of examiners A, B, and C were 0.42, 0.38, and 0.27, respectively. This finding emphasized on the significant role of the practitioner's experience in consistent preoperative interpretation of the radiologic landmarks of IAN injury.

In conclusion, this study showed an unsatisfactory level of objectivity and reliability in assessing panoramic radiographic predictors of IAN injury. It was found that assessment of the panoramic radiographic risk factors became more consistent as the practitioner's work experience was increased. Considering the low accuracy of panoramic radiography that was reported by other authors and the unsatisfactory level of objectivity and reliability in assessing radiographic risk predictors observed in the present study, it can be concluded that panoramic images should not be relied upon for preoperative prediction of IAN injury. Inconsistency in assessing the radiographic risk predictors of IAN injury and misinterpretation of these landmarks may adversely affect the clinical judgment of a practitioner and put the patient at risk of inadvertent postoperative nerve damages, so the use of advanced imaging techniques such as cone beam computed tomography is warranted.

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Conflict of interest statement The authors declared that they have no conflict of interest.

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