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RESEARCH PAPER

Proximity of Impacted Mandibular Third Molars to the Inferior Alveolar Canal and Its Radiographic Predictors: A Panoramic Radiographic Study

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Abstract
Purpose To assess the radiographic proximity of impacted mandibular third molars to the inferior alveolar canal on panoramic radiographs. The radiographic distance between the impacted mandibular third molars and inferior alveolar canal and the reliable radiographic risk predictor signs that indicate close proximity between these two structures were evaluated.
Methods The study comprised of 64 subjects with 68 symptomatic impacted mandibular third molars for whom panoramic radiographs were made. The radiographs were interpreted for type of impaction, radiographic distance between impacted mandibular third molars to inferior alveolar canal and presence of one or more of the seven radiographic risk predictor signs. Further, these teeth were surgically removed and the proximity was assessed based on the exposure of inferior alveolar canal/nerve which was considered as Gold standard.
Results The overall mean distance from the impacted mandibular third molars to inferior alveolar canal was −0.50 mm. Most of the samples (61.8 %) extended beyond the superior border of the inferior alveolar canal with a mean distance of −1.40 mm. Mesioangular impactions were found to be in the close proximity (−1.14 mm) to inferior alveolar canal than any other type. Interruption of the white line was the only statistically significant radiographic risk predictor sign $p = 0.006$ (< 0.05) that indicated close proximity of impacted mandibular third molars to inferior alveolar canal.
Conclusion It can be concluded that panoramic radiographs are reliable in assessing the proximity of impacted mandibular third molars to inferior alveolar canal. Mesioangular impactions are more closely placed to inferior alveolar canal and interruption of the white line is the most reliable risk predictor sign on the panoramic radiographs.

Keywords Panoramic radiographs · Inferior alveolar canal/nerve · Impacted mandibular third molars · Radiographic risk predictor sign

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Introduction

In the eruption sequence, third molars are the last to erupt and when properly positioned they emerge between the ages of 18–24 years. Approximately 40 % of these fail to erupt and become partially or completely impacted in bone, which is mainly attributed to tooth-jaw size discrepancy [1–3].

Mandibular third molars are the most frequently impacted teeth and are associated with various pathoses ranging from infection, inflammatory to cystic lesions necessitating their surgical removal. Neurosensory disturbances related to the inferior alveolar nerve [4, 5] due to the close anatomic relationship between the roots of mandibular third molars and the inferior alveolar canal [6] is one of the most grave complications of such a procedure. The prevalence of inferior alveolar nerve paraesthesia following third molar surgery ranges approximately from 0.4 to 8.4 % according to different studies [6]. Therefore pre-operative radiographic assessment of the proximity of these two structures becomes an essential measure before surgical removal of impacted mandibular third molars.

Panoramic radiographs are the most commonly employed pre-operative radiographs. Though newer imaging modalities exhibit higher qualities, the reduced accessibility and high cost have not made them very popular.

Investigations so far have individually studied the distance of impacted mandibular third molars from the inferior alveolar canal and different signs on the panoramic images which are believed to indicate the close proximity of mandibular third molars to the inferior alveolar canal. Studies addressing both these parameters have been far and few in between. Also, such studies have been sparsely conducted on panoramic radiographs alone.

Consequently, this study was designed with an aim to assess the proximity of impacted mandibular third molars to the inferior alveolar canal and determine the reliable radiographic risk predictor signs that indicate the same on panoramic radiographs.

Materials and Methods

Ethical clearance was obtained from the Institutional Ethical Committee prior to conducting the study. Sixty four subjects of either gender in the age range of 20–40 years, were selected by simple random sampling.

The inclusion criterion was (1) individuals presenting with symptomatic unilateral or bilateral impacted mandibular third molars with presence of ipsilateral second molars. The exclusion criteria were individuals with (1) history of trauma/surgery to the mandible, (2) developmental anomalies affecting the jaws and (3) clinical and/or radiographic evidence of pathologies of the impacted mandibular third molar teeth or mandible which could obscure the visualization of the periapical region or inferior alveolar canal.

A written informed consent was obtained from the subjects so selected. Panoramic radiographs were made for each study subject using standard exposure and processing protocols and were interpreted under ideal viewing conditions. The type of impaction of mandibular third molars was identified by the method adapted by Winter [7]. Subsequently, they were categorized as vertical, horizontal, mesioangular or distoangular impactions.

Radiographs were then interpreted cautiously for the following:

(a) *Radiographic distance between impacted mandibular third molars and inferior alveolar canal*. The distance in millimetres between the inferior most part of the tooth and the superior border of the inferior alveolar canal was measured using a digital vernier caliper. In instances where the inferior most part of the tooth was below the superior border of inferior alveolar canal a 'negative numerical' value was designated and vice versa. The values obtained were corrected for the magnification factor of 20 % (as specified by the manufacturer).

(b) *Radiographic risk predictor signs*. Seven radiographic risk predictor signs were assessed on the panoramic radiographs. The consensus of three oral radiologists was considered in evaluating the presence of each of the following sign.

1 *Darkening of the root*: Loss of root density in a tooth that is impinged upon by the canal.
2 *Interruption of the white line*: Discontinuity of the superior radio-opaque line that constitutes the superior border of the inferior alveolar canal.
3 *Diversion of the canal*: A change in the direction of the canal while crossing the mandibular third molar.
4 *Deflection of the root*: An abrupt deviation of roots near the canal.
5 *Narrowing of the root*: Narrowing of the tooth roots where the canal crosses.
6 *Narrowing of the canal*: An abrupt decrease in the width of the canal while it crosses the root apices.
7 *Dark and bifid root apex*: A loss of root density in a tooth that is impinged upon by the canal with bifid apex of the root.

Presence of radiographic risk predictor signs, either single or multiple (in combination) on panoramic radiographs was considered as close to inferior alveolar canal radiographically.

A single experienced oral surgeon subsequently performed the surgical extraction of all the impacted mandibular third molars as per his discretion. The surgeon had preoperative access to the panoramic radiographs but was blinded regarding the radiographic proximity parameters (distance and risk signs) assessed by the radiologists prior to the third molar surgery. The surgical proximity of the impacted mandibular third molars to the inferior alveolar canal was assessed after copious irrigation of the socket and direct visualization of the inferior alveolar canal as follows:

1 *Close*: Inferior alveolar canal/nerve visible after extraction
2 *Not Close*: Inferior alveolar canal/nerve not visible after extraction

The recordings at/after surgery were considered as 'Gold standard' for radiographic registrations with respect to measurements and radiographic signs.

Statistical Methods

The data tabulated was subjected to Chi-square/Crosstabs test, Independent-Samples t Test and One-Way ANOVA to

obtain the results. Sensitivity, Specificity, Positive predictive value (PPV), Negative predictive value (NPV) and Odd's ratio were calculated for each risk predictor sign.

Results

The total study sample constituted 68 impacted mandibular third molars among 64 subjects.

There were 42 (65.6 %) males and 22 (34.4 %) females and the male to female ratio was 1.9:1. The overall mean age of the study group was 27.64 years (SD 6.043). The mean age of the male subjects was 28.45 years (SD 6.275) and of female subjects was 26.09 years (SD 5.371).

Among the 68 impacted mandibular third molars, 40 (58.8 %) were present on the right side and 28 (41.2 %) on left side. Thirteen (19.1 %) were vertical impactions, 23 (33.8 %) horizontal impactions, 29 (42.6 %) mesioangular impactions and three (4.4 %) were distoangular impactions (Table 1).

Table 1 Descriptive statistics summary

Number of subjects	64
Number of samples	68
Gender distribution	
Male	42 (65.6 %)
Female	22 (34.4 %)
Mean age of the study group	27.64 years (SD 6.043)
Male subjects	28.45 years (SD 6.275)
Female subjects	26.09 years (SD 5.371)
Side distribution	
Right side	40 (58.8 %)
Left side	28 (41.2 %)
Type of impactions	
Vertical impactions	13 (19.1 %)
Horizontal impactions	23 (33.8 %)
Mesioangular impactions	29 (42.6 %)
Distoangular impactions	3 (4.4 %)

Radiographic distance between impacted mandibular third molars and inferior alveolar canal

The overall mean distance from the impacted mandibular third molars to inferior alveolar canal was −0.5011 mm (SD 1.719). Forty two (61.8 %) samples extended beyond the superior border of the inferior alveolar canal with a mean distance of −1.4033 mm (SD 1.479) and 26 (38.2 %) lay above the superior border of the inferior alveolar canal with a mean distance of 0.956 mm (SD 0.869) (Table 2).

Radiographic Risk Signs and Correlation with Surgical Findings (Gold Standard)

Radiographic risk predictor signs either single or multiple (in combination) were seen in 36 (52.9 %) (Positive samples) and no signs were observed in 32 (47.1 %) (Negative samples) of the 68 total samples (Table 2). Among the 36 positive samples, 23(64 %) showed single and 13(36 %) showed multiple (in combination) radiographic risk predictor signs. *Interruption of the white line* was noted in 22(32.4 %) and was the most commonly observed radiographic risk predictor sign (Table 3).

On surgical extraction, 10 (14.7 %) samples were found to be *close* and 58 (85.3 %) were *not close* to the inferior alveolar canal among the 68 samples.

On correlating surgical with radiographic findings, 9 (13.2 %) among the 36 positive samples were found to be *close* to the inferior alveolar canal and one (1.5 %) among the 32 negative samples was found to be *close* to inferior alveolar canal. The p value was 0.011 (<0.05) and was statistically significant. The sensitivity, specificity, positive predictive and negative predictive values were 90 , 53.4 , 25 , 97 % respectively. The odd's ratio (confidence interval) was 0.097 (0.012–0.814).

Type of Impaction and Proximity to Inferior Alveolar Canal

Upon radiographic evaluation, the mean distance of the 13 vertically impacted teeth from inferior alveolar canal

Table 2 Type of impaction with their mean distance, radiographic and surgical findings

Type of impaction	Number of samples	Mean distance	Number of samples showing radiographic risk predictor signs	Number of samples found to be close on surgical evaluation
Vertical impactions	13	−0.3003 mm (SD 1.12185)	7 (53.8 %)	2 (15.4 %)
Horizontal impactions	23	0.0561 mm (SD 1.39)	9 (39.1 %)	3 (13.0 %)
Mesioangular impactions	29	−1.1372 mm (SD 2.05067)	19 (65.5 %)	5 (17.2 %)
Distoangular impactions	3	0.5067 mm (SD 0.42046)	1 (33.3 %)	0 (0 %)
Total	68	−0.5011 mm (SD 1.719)	36 (52.9 %)	10 (14.7 %)

*Statistically significant ($p < 0.05$)

Table 3 Individual Radiographic risk signs

Sign	Radiographic findings	Surgical findings	*p* value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	OR (CI)
Darkening of the roots	18 (26.5 %)	3 (4.4 %)	0.784	30	74	16.67	86	1.229 (0.281–5.368)
Interruption of the white line*	22 (32.4 %)	7 (10.3 %)	0.006	70	74	32	93.5	6.689 (1.531–29.228)
Diversion of the canal	3 (4.4 %)	1 (1.5 %)	0.351	10	97	33	86	3.111 (0.255–37.959)
Deflection of the roots	0	0	0	0	0	0	0	0
Narrowing of the roots	1 (1.5 %)	0	0.676	0	98	0	85	0
Narrowing of the canal	7 (10.3 %)	1 (1.5 %)	0.974	10	89.7	14	85	0.963 (0.103–8.975)
Dark and bifid root apex	0	0	0	0	0	0	0	0

PPV positive predictive value, *NPV* negative predictive value, *OR (CI)* odd's ratio (confidence interval)

* Statistically significant ($p < 0.05$)

was −0.3003 mm (SD 1.12185) and two (15.4 %) of them were surgically found to be *close* to inferior alveolar canal. The 23 horizontally impacted teeth had a mean distance of 0.0561 mm (SD 1.39) and three (13.0 %) among them were surgically *close*, 29 mesioangularly impacted teeth had a mean distance of −1.1372 mm (SD 2.05067) and five (17.2 %) of them were surgically *close* and three distoangularly impacted teeth had a mean distance of 0.5067 mm (SD 0.42046) none of them being surgically *close* (Table 2).

Correlation of Individual Signs with the Surgical Findings

All the seven radiographic signs were evaluated individually and their association with the surgical findings was studied. *Interruption of the white line* was observed in 7 out of 10 surgically close cases and was the most statistically significant sign noted. $p = 0.006$ (<0.05) (Table 3).

Discussion

Inferior alveolar nerve paraesthesia following third molar surgery may be the result of direct trauma to the nerve or the pressure exerted over the nerve due to vessel rupture leading to hematoma formation. Removal of impacted mandibular third molars have been implicated as the main cause of permanent inferior alveolar nerve sensory deficiency outweighing other etiologic factors like implant and orthognathic surgery [8].

Panoramic radiographs are by far the most commonly employed pre-operative radiographs and form the basic screening radiographs which dictate the need for advanced imaging.

In the present study, most patients (66 %) were in the age group of 20–29 years similar to Mwaniki and Guthua [9] and Gupta et al. [10]. The mean age of the study samples was 28 years comparable to Knutsson et al. [11] and Nordenram et al. [12]. Males constituted most (66 %) of the study sample in accordance with Gupta et al. [10]. In contrast, studies by Jerjes et al. [5]. Knutsson et al. [11] and Szalma et al. [13] observed a female preponderance. This could be attributed to the variations in sample sizes involved.

Impacted mandibular third molars were commonly found on right side (58.8 %) in contrast to Gupta et al. [10] and Tay and Go [14] which could also be attributed to the variations in sample sizes involved.

Mesioangular impactions were most frequently noted (42.6 %) in agreement with Mwaniki and Guthua [9], Knutsson et al. [11], Sedaghatfar et al. [15], Gomes et al. [16] and Reddy and Prasad [17]. This could be attributed to the fact that the normal development and path of eruption of mandibular third molars is antero-superior [9].

Most of the impacted mandibular third molars (61.76 %) extended beyond the superior border of the inferior alveolar nerve in accordance with Miloro and DaBell [18]. These results suggest that impacted mandibular third molars lie in close proximity to the inferior alveolar canal.

Mesioangular impactions were closer to the inferior alveolar canal similar to Miloro and DaBell [18]. Further, both the studies observed that vertical impactions followed after that.

Certain radiographic signs have been suggested as risk factors predicting the close proximity of the impacted mandibular third molars to the inferior alveolar nerve by various investigators [19–21].

Mesioangular impactions (52.8 %) were most commonly found to be associated with radiographic risk predictor signs followed by horizontal impactions (25.0 %). To the best of our knowledge this is the first study correlating these two parameters and hence comparisons are not feasible.

In this study mesioangular impactions were associated with greater surgical exposure of the inferior alveolar canal

followed by horizontal impactions. However, they were statistically insignificant ($p > 0.05$). Similarly Blaeser et al. [20] also found no significant relationship between the type of impaction and inferior alveolar nerve involvement .

Amongst the 68 samples, 36 (52.9 %) showed one or more radiographic risk predictor signs of which 9 (13.2 %) positively correlated with surgical findings. This finding was statistically significant ($p = 0.011$) and indicates that presence of radiographic risk predictor signs on panoramic radiographs is significantly associated with involvement of inferior alveolar canal. The sensitivity was 90 % which signifies that panoramic radiographs predicted 9 out of 10 cases that were actually close to inferior alveolar canal.

This signifies that the reliability of panoramic radiographs in predicting the inferior alveolar nerve exposure is high when the proximity is assessed with respect to radiographic risk predictor signs. This is in accordance with Sedaghatfar et al. [15].

The specificity was 53.4 %, i.e 31 cases showed no radiographic signs out of the 58 cases that were actually not close to the canal surgically. The positive predictive value, i.e the probability that a patient will have a condition given a positive test result was 25 %. In context to our study it can be explained as only 9 of the 36 radiographs which showed radiographic risk predictor signs, actually were close to the inferior alveolar nerve when the Gold standard was applied.

Among the 32 samples that did not show any of the radiographic risk predictor signs, one (1.5 %) sample positively correlated with surgical findings. This sample was located at a substantial distance of −8.14 mm from the superior margin of the inferior alveolar nerve indicating that it was situated deep within the bone. Exposure of the inferior alveolar nerve in this sample probably resulted due to considerably higher surgical manipulation during its removal. Thus, the negative predictive value observed in the present study indicates that in 97 % of the samples with absence of radiographic risk predictor signs, there are minimal chances of inferior alveolar canal involvement.

Panoramic radiographs are assumed to be standard diagnostic tools in the preoperative assessment of mandibular third molars and their relationship with the inferior alveolar canal [22, 23] and have been advocated as the radiographs of choice where the facility is available [24]. As a protocol, the Finnish Student Health Service in Helsinki proposes use of advanced imaging techniques only when panoramic radiographs suggest a close relationship between the impacted mandibular third molar and the inferior alveolar canal [25]. Furthermore, a meta analysis by Atieh [26] to determine the diagnostic accuracy of panoramic radiographic markers in detecting the relationship between impacted mandibular third molar roots and the inferior alveolar canal suggested a reasonable diagnostic accuracy for panoramic radiography for the same.

On correlation of individual radiographic risk predictor signs with surgical findings (Gold standard) *interruption of the white line* was found to be statistically significant ($p = 0.006$) and was in accordance with Blaeser et al. [20], Rood and Shehab [19], Sedaghatfar et al. [15], Szalma et al. [13] and Ghaeminia et al. [22]. In the present study, a sensitivity of 70 % and specificity of 74 % was obtained for this sign which lies within the range of values obtained by Bell (34–63 %) [21] and other investigators [13, 15, 16, 19, 20]. The positive predictive value of 31 % and negative predictive value of 93 % observed in our study too lie within the range of values obtained by others researchers [16, 19–21].

Our study found that *'interruption of the white line'* was the most reliable radiographic risk predictor sign. Ghaeminia et al. [22] also observed a similar finding in their CBCT study. Nakagawa et al. [27] concluded that in 86 % of cases with *'interruption of the white line'* on panoramic radiography, CBCT images also showed contact between the third molar root and the inferior alveolar canal. Umar et al. [28] as well observed a similar finding.

The other signs evaluated in the study were not significantly associated with inferior alveolar nerve exposure statistically but were found reliable in various other studies. *'Darkening of the roots'* was found to be more reliable in a number of others studies followed by *'diversion of the canal'* contrasting with our study. A meta analysis stated that three signs namely *'darkening of the roots'*, *'interruption of the white line'* and *'diversion of the canal'* were associated with higher risk of inferior alveolar nerve injury [26]. These inconsistencies observed among studies could be attributed to the differences in the sample sizes, radiographic technique standardizations, subjective assessment of inferior alveolar nerve involvement and most importantly, the radiographic acumen and surgical expertise of the investigators.

All the radiographic risk predictor signs have higher negative predictive values which assert that the absence of any of the risk predictor signs is a strong indication of decreased risk of inferior alveolar nerve injury.

A combination of radiographic risk predictor signs was also observed in a few samples in our study but was statistically insignificant. This implies that presence of more than one radiographic risk predictor signs on the panoramic radiographs does not indicate a higher probability of close proximity of the impacted mandibular third molars to the inferior alveolar canal. This is in contrast to the findings of Szalma et al. [13] and others [15, 20, 21] who opined that presence of multiple radiographic risk predictor signs predicts a higher rate of inferior alveolar nerve involvement and needs to be studied further.

Blaeser et al. [20] suggested additional higher imaging when one or more radiographic risk predictor signs were observed on panoramic radiographs.

To conclude, this study demonstrated that conventional panoramic radiographs are dependable in determining the proximity of the impacted mandibular third molars to the inferior alveolar canal. It was observed that mesioangular impactions were the most common, and were most intimately related to the inferior alveolar canal in terms of distance and radiographic risk predictor signs. The study also established that *'interruption of the white line'* was the most reliable radiographic risk predictor sign which distinctly indicated the close proximity of the tooth to inferior alveolar canal.

The presence of radiographic risk predictor signs specifically *'interruption of the white line'* on panoramic radiographs as observed in our study should caution the dental surgeon regarding close proximity of the impacted mandibular third molars to the inferior alveolar canal. Alternative modes of treating symptomatic impacted mandibular third molars such as pericoronal ostectomy, coronectomy or orthodontic extractions could be employed in such situations [29–33].

Nonetheless, additional studies incorporating larger samples and advanced imaging modalities will be indispensable in justifying the findings of the present study.

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