Correlation of the radiological predictive factors of inferior alveolar nerve injury with cone beam computed tomography findings

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Abstract

Aim: This study assessed the radiological signs considered predictive of inferior alveolar nerve (IAN) injury and correlated them with findings from cone beam computed tomography (CBCT).

Material and methods: This was a prospective study of patients who underwent CBCT scanning of mandibular third molars when panoramic radiographs indicated an ‘increased risk’ of IAN injury during extraction.

Results: Seventy-eight per cent of the teeth identified showed darkening across the root. Thinning or perforation of the cortical plate was found on CBCT. The group that exhibited loss of radiopaque lines across the root (68%), all of the scans showed contact between the nerve and root, with loss of cortication of the canal. Thirty per cent of the cases exhibited diversion of the canal. There was contact with the tooth in all cases, with the nerve either coursing through the roots (33%) or being ‘sandwiched’ between the root and the cortex to such an extent that the distortion resulted in part of the nerve being displaced beyond the apex of the tooth, creating an apparent change in direction.

Conclusion: Loss of radiopaque line and diversion of the canal were both associated with loss of cortication of the canal on CBCT, indicating that there was contact between the root and the contents of the canal. These two signs are crucial predictive signs of increased risk of IAN injury during third molar extraction. Darkening of the root displayed root and nerve contact in 76.9% of the cases studied and therefore very likely to indicate risk.

Key words: cone beam CT, dental, inferior alveolar nerve, lower third molars, nerve injury, radiological signs

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Introduction

The removal of third molars is one of the procedures most commonly performed by oral surgeons. Dysfunction of the inferior alveolar nerve (IAN) after mandibular third molar extraction, although uncommon, is probably one of the most undesirable consequences of this, and is acknowledged to be very distressing for the majority of patients1. Altered function of the IAN may be perceived by the patient as a ‘tingling’, ‘numbness’ or as a burning or painful sensation affecting the ipsilateral lower lip, chin, gingivae and teeth. The frequency of occurrence of this complication is reported in the literature to vary widely, from 0% to as high as 17.4% (Table 1).

It is generally accepted that unless the root of a mandibular third molar appears to lie in close proximity to (in some cases overlaps) the inferior alveolar canal, there is little (if any) anatomical risk to the nerve, but surgical risk is also both operator- and technique-dependent. In order to determine the relationship between the nerve and the tooth, standard preoperative evaluation relies on panoramic imaging. Several radiological predictors have been proposed to indicate a close relationship of the tooth root and the canal8.
The three radiological signs previously reported to be most predictive of sensory disturbance following mandibular third molar removal are5,8,11–13
● Darkening of the root, which has previously been explained by a reduction of bulk of root substance due to the inferior alveolar canal or nerve grooving the root5,8,9,11
● Interruption of the ‘radiopaque line’ of the canal (white line), which has been attributed to the deep grooving or perforation of the root5,11, or a loss of the cortical margin of the canal so the root is in contact with the nerve14,15
● Diversion of the canal which has been interpreted as indicating that the canal had perforated the root and ‘been dragged’ upwards during subsequent tooth eruption11, or the root during development has displaced the nerve so that a change in direction appears14,15.

With the development of limited cone beam computed tomography (CBCT), the increasing availability of such scanners in the dental environment and benefit to patients in terms of reduced radiation dose offered by this type of imaging over conventional CT scanning, the value of CBCT to aid the evaluation of the anatomical relationship of the IAN and the position of third molars is beginning to be realised. These scans allow the surgeon to gain an appreciation in all dimensions of the precise relationship between the inferior alveolar canal and mandibular third molar. This enhanced understanding of anatomical relationships may necessitate an alteration of the surgical approach to the removal of the tooth or allow the surgeon to plan an alternative risk reducing surgical technique, for example coronectomy. Little work has been done to correlate the signs predictive of IAN injury seen on panoramic or periapical radiographs with findings on CBCT. Only darkening of the root17,18 and interruption of the radiopaque line14,19 have been reported previously.

This investigation was undertaken to re-evaluate the interpretation of the radiological ‘signs’ generally accepted to indicate heightened risk of disturbing the function or integrity of the nerve following mandibular third molar removal by comparing panoramic images with CBCT reconstructions.

**Method**

Patients referred for the removal of impacted mandibular third molars were routinely assessed on a number of clinics using conventional panoramic radiographs. Clinicians (of various grades) were requested to identify patients considered to be at ‘increased risk’ of IAN damage using the accepted criteria suggesting a ‘close relationship’ between the tooth and the canal8.

Only cases where the canal wholly or partially overlapped the roots and demonstrated one of the three most significant predictive signs: darkening of the root and interruption of the radiopaque line and diversion of the inferior alveolar canal, were included in this study. In addition, inclusion necessitated that the inferior alveolar canal was clearly identifiable mesial and distal to the lower third molar on panoramic radiographs.

The records of patients identified according to these criteria were then assessed independently by two of three experienced surgeons (CB, GU, OO). Radiographs were examined in a suitably darkened environment with a good quality light box, a viewing cone and magnification, to confirm the presence of at least one of the significant predictor signs. Only when both examiners agreed was the case considered to be ‘high risk’.

When these ‘high risk’ cases were considered for surgical intervention, a CBCT scan (3DX Accuitomo Morita Co. Ltd, Tokyo, Japan) was arranged. The patient received the minimum exposure by using a collimated 40 mm × 40 mm × 40 mm window. These

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**Table 1** Incidence of reported altered labial sensation following third molar removal

<table>
<thead>
<tr>
<th>Study</th>
<th>Temporary alteration sensation (%)</th>
<th>Permanent alteration sensation (%)</th>
<th>Unspecified time of altered sensation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Gϋlicher &amp; Gerlach3</td>
<td>3.6</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>Hill et al.4</td>
<td>&lt;5</td>
<td>0</td>
<td>5.17</td>
</tr>
<tr>
<td>Howe &amp; Poyton2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renton et al.4,6</td>
<td>17.4</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Rood7</td>
<td>6.3</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Rood &amp; Shehab8</td>
<td></td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>Rud9</td>
<td></td>
<td></td>
<td>0.4–2.4</td>
</tr>
<tr>
<td>Valmaseda-Castellόn et al.10</td>
<td>1.3</td>
<td>0.36</td>
<td></td>
</tr>
</tbody>
</table>

*This study examined the outcome of only those patients whose third molars were considered to be at increased risk of IAN injury.*
CBCT images were examined independently by two oral surgeons (JPR and GU) in a suitably darkened environment, using a high-quality screen. Regular breaks were taken to avoid examiner fatigue. In the majority of cases, the course of the nerve was followed distally from where the inferior alveolar foramen became evident to the mandibular third molar, so that there was no ambiguity on the scan as to which radiolucency represented the IAN.

The images were viewed in all dimensions in order to identify the relationship between the nerve canal, roots and surrounding bone. Only cases in which both examiners agreed with the assessment were the results included in the study. Where more than one predictor sign was present on the radiograph, each sign was examined independently.

**Results**

A total of 50 impacted third molars exhibiting a degree of image overlap plus at least one sign of high risk on plain radiograph were examined in 47 patients. The patient group consisted of 32 females (68%) and 15 males (age range 21–63 years, mean 33.66 years), with 54% of the third molars being on the left side. In the majority of cases, more than one sign of risk was visible on the radiographs (50 teeth displayed 88 signs Table 2).

**Darkening of the root (Fig. 1)**

This has previously been reported to be due to loss of tooth structure indicating ‘grooving’ by the canal or due to the loss of the cortical lining of the canal. This sign was evident in 39 of the 50 third molars (25 females, 14 males).

**CBCT findings**

In only one of these cases was loss of tooth substance (grooving) identified (2.6%).

In all cases, however, there was loss of integrity of the cortical plate structure (Table 3) within the lingual (30 cases), buccal (three cases) or both (six cases) of the cortical plate. This was due to either the nerve canal (14 cases) or tooth substance (17 cases Fig. 2) being within the cortex (Table 4). In eight cases, ‘grooving’ of the cortical plate was due to both tooth and nerve canal.

<table>
<thead>
<tr>
<th>Table 2 Distribution of signs present on 50 teeth examined</th>
</tr>
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<tbody>
<tr>
<td>Radiological sign</td>
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<tr>
<td>Darkening of root</td>
</tr>
<tr>
<td>Interruption of radiopaque line</td>
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<tr>
<td>Diversion of inferior alveolar canal</td>
</tr>
<tr>
<td>Total</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3 Cortical plate exhibiting thinning where darkening featured as a predictive sign</th>
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<tbody>
<tr>
<td>Cortical plate with thinning</td>
</tr>
<tr>
<td>Lingual</td>
</tr>
<tr>
<td>Buccal</td>
</tr>
<tr>
<td>Both</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4 Cause of cortical bone loss</th>
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</thead>
<tbody>
<tr>
<td>Cortical plate with bone loss</td>
</tr>
<tr>
<td>Lingual</td>
</tr>
<tr>
<td>Buccal</td>
</tr>
<tr>
<td>Both</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

**Figure 1** Darkening across the root of the lower left third molar shown on panoramic radiograph with schematic diagram (canal in green).
Of the 22 cases where cortical plate loss was due in part to the position of the nerve (14 + 8), 20 cases involved loss of structure of the lingual cortical plate and two involved the buccal cortical plate.

In 25 cases (17 + 8), there was loss of cortical plate structure due to part of the tooth being situated within it (5 buccal, 18 lingual, 2 both). Where loss of both cortical plates was due to the position of the tooth, the nerve passed through the substance of the tooth that is perforated the root (Figs 3 and 4).

Of the 38 cases where grooving was not evident on the CBCT, the nerve was in contact with the tooth in 29 cases, that is the other nine cases displayed no contact between tooth and nerve (Figs 5 and 6).

In one case (Figs 7 and 8), a substantial portion of the tooth was found to be present within the thinned lingual plate, but the localised darkening on the plain film
appeared to coincide with the superimposed image of the (soft tissue) canal which was separated from the tooth by cancellous bone (there was no loss of radiopaque lines).

**Interpretation**

Darkening, evident on plain films does not indicate grooving of the tooth root but a reduction in the thickness of either the buccal or lingual cortex by the nerve, root or both. The linear image of darkening can also be explained by the superimposition of the nerve canal over the area of cortical bone loss (Figs 1, 2, 5 and 6).

**Interruption of the radiopaque line (Fig. 9)**

This has been considered to indicate close contact between the canal and tooth, resulting in loss of part of the cortical margin of the canal.

This sign appeared in 34 of the 50 cases (22 females, 12 males).

**CBCT findings**

Loss of cortication of the inferior alveolar canal was evident in all of the cases (Fig. 10), with the contents of the canal being in contact with the tooth in every case. Additionally, 21 (62%) demonstrated loss of the canal cortication attributed to contact of the canal with the lingual (17 cases) or buccal (four cases) cortical plates.

**Interpretation**

On plain films, loss of a radiopaque line does indicate ‘contact’ between the IAN canal and tooth structure.
**Diversion of the canal (Figs 11 and 13)**

This has been taken to indicate close contact between the IAN and the mandibular third molar and has been explained by the developing root causing displacement of the course of the canal.

This sign was present in 15 of the 50 cases (10 females, 5 males).

**CBCT findings**

There was contact between the canal and root in all 15 cases. All 15 cases also demonstrated loss of cortication of the canal at the point of contact. In 10 cases, the nerve was ‘sandwiched’ between the cortical plate and root to such an extent that the nerve deviated around the root apex (Fig. 12).

Where the nerve was not positioned between tooth and the cortical plate (five cases), the diversion was a result of the nerve weaving itself between the roots (Figs 13 and 14).

**Interpretation**

Diversion of the canal seen on plain radiograph correlates with either the nerve coursing between the roots of the lower third molar, or the nerve being ‘sandwiched’ between the root and cortical bone to such an extent distortion of the nerve results in an alteration of direction.

**Discussion**

Panoramic radiography is invaluable in illustrating the proximity of the IAN and mandibular third molar.
CBCT is proving to be increasingly beneficial in determining the precise relationship between these two structures in those individuals where the panoramic radiograph suggests the relationship to be close\(^2\). The CBCT images can be reformatted with minimal distortion allowing the canal and tooth to be viewed in all dimensions\(^2\). Its use results in patients receiving a greater radiation dose compared to standard radiography; therefore, it is not appropriate for CBCT to be used as the first routine imaging technique, and should be applied when the benefits of the additional exposure are likely to be considerable.

The present study reveals some misconception in the interpretation of the radiological predictors traditionally believed to be indicative of increased risk of IAN damage. The study was designed to examine the three findings said to be significantly related to IAN injury\(^4\): darkening of the root, interruption of the radiopaque line and diversion of the inferior alveolar canal.

Numerous studies have previously attributed darkening across the root to reflect grooving of the root and hence loss of tooth substance\(^5,8,11,22\). Grooving is indicated by the existence of a concavity or invagination in...
which the canal will lie. Curvature of the root apex
around the canal may be illustrated by a hook or
notch\textsuperscript{22}. This concept was recently evaluated using with
CBCT\textsuperscript{17,18}, and it was proposed that the darkening is not
due to the loss of calcified substance in the tooth, but
the loss of calcified substance of the buccal and/or
lingual cortical plates. Our study supports this conclu-
sion, and attributes the darkening not to loss of tooth
substance, but in fact to thinning of a cortical plate.
Only one case demonstrated grooving of the tooth
(2.6\%), but thinning of the cortical bone was also
present. Also noted in our findings was that 36 cases
demonstrated thinning of lingual cortex and in some
cases this was so pronounced that there was perfora-
tion of the lingual plate. This finding is highly relevant
to the oral surgeon as it may alter the technique of
extraction, thereby lowering the risk for lingual
nerve damage, fracture of the lingual cortex or hernia-
tion of root fragments into anatomical spaces such as
lingual fossa or sublingual space. In addition, such risks
can be discussed further with the patient thereby
allowing the surgeon to obtain a more secure informed
consent.

In some cases, loss of the cortical plates occurred
adjacent to the crown of the tooth, in addition to the
roots. It was noted however the panoramic radiograph
of these cases did not exhibit darkening in the coronal
area. This could be due to the superimposition of the
radiopaque enamel of the crown masking any darken-
ing which may be present, whereas in the apical
portion, there is superimposition of the radiolucent
canal over an area of bone loss. Moreover, the linear
appearance of darkening across the roots can be
explained by the superimposition of the nerve coin-
ciding with the area of cortical bone loss.

In conclusion, the darkening of the root is not due to
the grooving of the tooth as proposed in previous
studies, but due to the grooving of the cortical plate.

Although darkening does not indicate grooving of
the tooth, 30 of the 39 cases of third molars in this
group were in contact with the IAN. Thus, manipula-
tion of the tooth during extraction may exert some
force on the nerve, which may result in some altered
sensation, confirming that this sign is predictive of an
increased risk of nerve injury.

The interruption of the ‘radiopaque lines’ has been
attributed to contact of the roots with the nerve\textsuperscript{5,8,11,14,19}. Our study corroborates this finding.
One hundred per cent of cases exhibiting loss of the
radiopaque line on panoramic radiographs also dis-
played loss of cortication of the canal on CBCT, with
the roots in contact with the contents of the canal.
Therefore, it seems highly probable that if these teeth
were to be extracted, the nerve would be exposed and
may be visible in the socket\textsuperscript{19}. There is also a risk of
IAN damage during extractions to this group of
patients as manipulation of the root may inadvert-
ently cause compression of the nerve. It was also
noted that in four patients of this group (12\%), the
nerve either coursed between the buccal and lingual
roots of the tooth or perforated the root. CBCT
imaging will aid planning the surgical approach to
extractions in these patients.

In conclusion, loss of a radiopaque line of the canal
across the root does indicate contact with the nerve and
its contents, as there is loss of the cortical structure of
the canal and confirms potential injury to the nerve
during extraction.

Diversion of the nerve is said to be attributed to the
nerve being displaced during the development of the
tooth\textsuperscript{11,16}. In our study, diversion was found to be
related to the distortion of the nerve as it passed by the
root (10/15 cases), or passing between the roots (5/15
cases). All cases exhibited nerve and root contact.
Manipulation of the tooth during extraction may result
in compression of the nerve.

In their 2005 article, Renton \textit{et al.}\textsuperscript{6} described a ‘new’
radiological feature: the juxta-apical area and sug-
gested that it was predictive of an increased risk of
nerve injury. This ‘new sign’ was also noted the pan-
oramic radiographs of some of the patients in our study
(Fig. 15).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure15}
\caption{Panoramic radiograph illustrating
the ‘juxta-apical area’ on the lower right third
molar.}
\end{figure}
When these areas were examined on the CBCT, the appearance related to a particularly large cancellous bone space. This phenomenon was noted on several scans (Figs 16 and 17). Thus our study suggests that the ‘juxta-apical area’ per se is not a sign of increased risk, but rather a superimposition of the canal over large cancellous bone spaces – an image created by cancellous bony architecture rather than pathology.

The results of our study suggest that for those patients where plain film indicates an increased risk of IAN injury during extractions of mandibular third molar, CBCT can clarify the position of the nerve in all dimensions and improve surgical planning to reduce the risk of this complication. It may also prove to be reassuring when no contact between the root and the nerve is observed on CBCT and therefore patients can be reassured that there is no increased risk of nerve injury.

**Conclusion**

CBCT has significantly improved our understanding of the relationship between mandibular third molars and the inferior alveolar canal previously described by panoramic radiography. We have demonstrated that darkening of the root correlates to thinning of lingual or buccal cortical plate (by either the tooth or the nerve.) Loss of radiopaque lines indicates that the canal and hence its contents are in contact with tooth. Diversion of the canal correlates to the course of the nerve being altered as it contacts and passes the roots due to space restriction in the mandible.

Of the predictive signs observed on panoramic radiographs, loss of cortication and/or diversion of the canal are highly suggestive of nerve/root contact.

All three signs reflect a risk relationship between tooth and nerve which is confirmed by CBCT. Planning the surgical removal of lower third molars can be effectively and precisely enhanced with the use of CBCT, which provides not only an accurate understanding of the position of the nerve in relation to the third molar, thereby facilitating a risk reducing surgical approach or treatment (Figs 18–20), but also other potential complication, for example, risk of herniation of tooth fragments into the lingual fossa when the lingual cortical plate, is thinned substantially.
References

8. Rood JP, Nooraldeen Shehab BAA. The radiological prediction of inferior alveolar nerve injury during third