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Comparative Study Of Orthopantomograph & Cone Beam Computed Tomography As Pre-Operative Diagnostic Tools For Lower Third Molar Surgery

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Thesis Title: Comparative Study of Orthopantomograph & Cone Beam Computed Tomography As Pre-operative Diagnostic Tools For Lower Third Molar Surgery

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Introduction

Background information

Injury to the inferior alveolar nerve and lingual nerve is an uncommon but important complication in the surgical removal of impacted mandibular third molar teeth.\(^{(1)}\)\(^{(a)}\) The variable anatomic position of the lingual nerve increases the risk of damage to the lingual nerve, with the risk of lingual nerve injury ranging between 0.1% to 22%\(^{(2)}\)\(^{(a)(b)}\). Similarly the variable relationship of the inferior alveolar nerve to the root of the mandibular third molar tooth greatly increases the risk of injury to the inferior alveolar nerve.\(^{(1)}\)\(^{(a)(b)}\) The risk of inferior alveolar nerve damage ranges from 0.26% to 8.4%.\(^{(2)}\)\(^{(b)}\) Injury to the inferior alveolar nerve manifests as a sensory disturbance of the lower lip and chin to the midline, whilst injury to the lingual nerve manifests as a sensory and some taste disturbance from the tongue.\(^{(1)}\)\(^{(a)}\) The inferior alveolar nerve is contained within the mandibular canal which in turn is invested within the mandible and surrounded by bone, so providing the inferior alveolar nerve some degree of protection from injuries.\(^{(1)}\) The investment within bone also enables various radiographic imaging techniques to be utilized to predict with reasonable accuracy the risks of injury to the inferior alveolar nerve, which may influence the surgical treatment plan and approach, therefore in turn the degree of altered sensation from the lip and chin to the midline.

Mandibular Third Molar Surgery

Mandibular third molar surgery is a common and relatively uncomplicated elective procedure to remove or modify the mandibular third molar tooth. The surgery is commonly indicated where there is infection, bony pathology, soft tissue pathology or damage to the adjacent tooth.\(^{(4,5)}\) Infections may develop from pathology arising directly or indirectly from third molar teeth or associated structures, which may be localized or may spread rapidly into tissue spaces, including submandibular, submasseteric or retropharyngeal spaces.\(^{(4)}\) Floor of mouth infections, of odontogenic origin, can lead to the patient presenting with fever and malaise, and compromised airway an obvious life threatening emergency in the form of Ludwig’s Angina.\(^{(5)}\) The management would involve not only that of the presented emergency, but also of the lower third molar tooth. In other situations bony pathology may develop and expand through the mandible resulting in pathological fracture of the mandible, whilst soft tissue pathology may develop and be involved in infection, pain and unbearable discomfort to the patient.\(^{(3,9)}\) There may also be damage to adjacent teeth with food trapping and development of caries. The common factor in all of these presentations is the lower third molar tooth and indication for its removal in order to resolve or prevent the development of pathology.\(^{(4,5)}\)

![Image](image1.png)

Figure 1 Demonstrating the three most common presentations for pathology related to third molar teeth.

\(^{a}\) The reference made here to the incidence of damage to the lingual nerve is for the purpose of comparison to the incidence of damage to the inferior alveolar nerve. The lingual nerve cannot be identified by radiograph and is not the subject of this study.

\(^{b}\) Based on a literature review study by Y.Y. Leung and L.K. Cheung.\(^{(2)}\)
Third molar surgery may also be indicated as a prophylactic measure to prevent the development of pathology and complications, including infections and damage to surrounding structures. Third molar surgery is challenging for the surgeon as the exact relationship between the roots of the mandibular third molar teeth and the inferior alveolar canal is hard to predict pre-operatively and so the position of the inferior alveolar canal is unknown. Further to this, for the best part of the procedure the surgeon is operating blindly, as a two dimensional image cannot display the variable relationship. The surgeon needs to be able to carry out detailed preoperative evaluation of the mandibular third molar region and be able to apply this to a surgical treatment plan, and then carry out the subsequent clinical procedure accordingly to formulate the surgical treatment plan in order to ensure a positive outcome for the patient.\(^{(9)}\)

Third molar surgery poses intraoperative risks including damage to the inferior alveolar canal by instrumentation, displacement of the roots to a compromised position, as well as fractures of the roots or the alveolar process of the mandible.\(^{(2,7)}\) This may result at times in adverse and undesirable postoperative complications, including pain and infections, as well as altered sensations to lip, chin and or tongue. Difficult surgical challenges and unpredictable surgical outcomes can be caused by wide variations in the position and anatomy of the mandibular third molar roots, and relationship of these roots to the variable anatomical position within the body of the mandible of the mandibular canal containing the Inferior Alveolar Nerve (IAN). In certain population numbers, there may also be additional anatomical branches of the mandibular canal\(^{(6)}\), which may further complicate this variable relationship with the mandibular third molar roots.\(^{(3)}\) Such variations of the anatomy within this region and the associated complexity may at times present the surgeon with inadvertent crush injury, stretch injury or even severing of the inferior alveolar nerve.\(^{(9,10,9)}\)

Appropriate imaging and treatment planning results in predictable surgical outcome. When the surgeon carries out pre-operative intraoral examination of the mandibular third molar region the crown of the third molar may be visible as either fully erupted, partly erupted or unerupted.\(^{(7)}\) However, the roots and the neurovascular bundle are invested within bone and so their relative relationship is hidden from the surgeon’s vision. Diagnostic radiographic imaging will provide the surgeon with some information regarding the type of impaction, the shape of the roots and the anatomical position of these roots to the neurovascular bundle. Such imaging of the surgical site allows the surgeon to plan the surgical approach, including how much bone is required to be removed, as well as where and how the tooth is required to be sectioned to release it from its impaction.\(^{(11-14)}\)

The surgical approach and the ensuing safe outcome is directly influenced by the relative relationship of the inferior alveolar canal to the mandibular third molar roots.\(^{(15,16,17)}\) Periapical radiograph can be used as a pre-operative diagnostic and treatment planning tool.\(^{(12)}\) Periapical radiography requires relatively low radiation dosage and so low exposure of the patient to radiation. In addition to this the periapical radiograph being a two dimensional flat film image will have minimum distortion effects and so vital structures like the inferior alveolar canal and the third molar roots will appear clearly. However, the periapical radiograph is limited by small field of view and so limiting the overall appraisal of the surgical site and the relative position of the various important vital structures within the surgical site. The overall extent of any associated pathology would also be hard to view, as well as the degree of impaction of the third molar tooth, and so may require multiple films at different angles in order to obtain the desired visualization of the area. At times the course of the IAN canal through the mandible may be tortuous and this would be limited or not at all possible to predict on an intraoral periapical plain film radiograph with limited field of view. The IAN and the mandibular third molar roots may appear clearly on an intraoral periapical plain film radiograph but their relative position would be hard to predict. Likewise, anatomical variations
in the number of roots and their variable anatomical positions are hard to view on an intraoral periapical plain film radiograph with such limited field of view.

The most appropriate and conventional radiographic techniques relied on by surgeons for many years has been an orthopantomograph (OPG).\(^{(12, 18)}\) An overall view of all of the important anatomical structures is possible in a single OPG radiograph scan. The relative relationship and proximity of the mandibular third molar roots to the inferior alveolar canal can be predicted by several radiographic signs displayed on an orthopantomograph (OPG), including darkening of the roots, deflection of the roots, narrowing of the roots, dark and bifid roots, interruption of white line(s), diversion of the inferior alveolar canal and narrowing of the inferior alveolar canal.\(^{(6, 12, 13, 19)}\) The display of one or more of these radiographic signs on an OPG radiograph is indicative to the surgeon of the relative intimate relationship of the inferior alveolar nerve with the roots of the mandibular third molar. Whilst this alerts the surgeon to be careful in the approach to surgery, it may not necessarily be able to closely guide the surgeon as to how to make that approach to surgery.\(^{(1, 12, 13, 16)}\)

An OPG is a plain film panoramic view of three dimensional structures and so is limited with its depth of view and so hard to predict whether an anatomical structure of concern is appearing in the foreground or background of the image. As with a single intraoral plain film radiographic view the relative relationship of two or more structures superimposed in the same line of view is hard to predict on an OPG radiographic view. Unlike a periapical intraoral plain film radiograph it is not practical to obtain multiple views of these structures with the tube shift technique used on intraoral periapical radiographs. The wrong positioning of the OPG scanner tube in relationship to the airway and other soft tissue anatomical structures will limit optimal radiographic view with ghosting effects. Likewise, positioning errors with hard tissue anatomic structures such as the spinal column will result in superimposition of structures. A single panoramic scan of a three dimensional structure also results in distortion from the centre of the image to peripheral margins.\(^{(11)}\) The limitations in the depth of view, superimposition of structures and distortion of the images makes it particularly hard to predict on an OPG radiograph the relative relationship of the inferior alveolar nerve and roots that may be particularly intimate. Additional imaging can be used, such as intraoral Periapical radiographs and mandibular occlusal films or even extraoral lateral cephalograms.\(^{(12)}\) However, the diagnostic quality of these additional images may be once again limited by the field of view and the dimension of view. Other imaging techniques such as Helical Beam CT may be relied upon and utilized as more accurate, however multiple helical beams scans required of the area of interest in order to obtain diagnostic quality slices of the region renders the patient to be exposed to more than the necessary amounts of radiation dosage.\(^{(19-24), (17)}\) In addition to this, the high radiation dosage and multiple scans of the helical beam scanner may result in undesirable scatter effects from the metallic restoration of teeth, resulting in poor diagnostic outcome with some studies.\(^{(19-24)}\)

Cone-Beam Computed Tomography (CBCT) is a relatively new radiographic imaging method which may provide the ability to predict more accurately the relationship of the root(s) to the inferior alveolar canal, and therefore a more predictable and favourable outcome.\(^{(17, 25-34)}\) This has been facilitated by the ability to acquire DICOM data set from a single cone beam exposure of the region of interest and utilize this data set in computing software to manipulate and visualize the relationship in different dimensions. CBCT has been in use at Sydney’s Westmead Centre for Oral Health (WCOH) since 2006. Prior to 2006, however, the sole imaging method was OPG radiographs. The purpose of this pilot study is to evaluate whether OPG alone or utilisation of OPG and CBCT together provides the more predictable outcome following lower third molar surgery where there has been a close relationship of the roots to the inferior alveolar canal.
Anatomy of the mandibular third molar region

Understanding the normal anatomy of the third molar region and variations to this normal anatomy plays an important role in the safe surgical approach to removal of mandibular third molar teeth.

Root anatomy and position of the third molar tooth

The normal anatomical variability of the roots of the mandibular third molar tooth vary from single rooted conical shape to fused multi-rooted or divergent multi-rooted (two, three or four roots) presentation, and these can be narrow, bulbous and/or curved. (35) The presentation of the mandibular third molar tooth in the mandible can also vary from vertical, mesioangular, distoangular, horizontal, oblique or transverse, and may be erupted, or partially erupted with soft tissue impaction or bony impaction, or unerupted with partial or complete bony impaction. (36) An impaction of a tooth is the lodgement of the tooth in question against a nearby anatomical structure such as soft tissue, bone or another tooth, which prevents that tooth from erupting into its normal position in the dental arch.

The wide variations in the position and anatomy of the mandibular third molar roots present a significant surgical challenge to the surgeon. (8, 37) Further to this, the relationship of these roots to the variable position and anatomy of the mandibular canal containing the Inferior Alveolar Nerve may at times present the surgeon with even more difficult surgical challenges, with unpredictable and undesirable surgical outcomes. (8, 37) (1) Inadvertent crush injury, stretch injury or even severing of the inferior alveolar nerve may occur where the relationship is not clear. A pre-operative diagnostic method that may highlight and illustrate this relationship will guide the surgeon and provide the desirable outcome for all concerned. (1)

Impacted mandibular third molars have been traditionally classified in three main ways: (38)

These classifications of mandibular third molar teeth has traditionally been used to identify the difficult surgical cases.

1) Based on the Nature of the Overlying Tissue: (38)

Soft Tissue Impaction. When the height of the tooth’s contour is above the level of the surrounding alveolar bone and the superficial portion of the tooth is covered only by soft (though this can be dense and fibrous) tissue. Soft tissue impaction is usually the easiest of type of impacted tooth to remove. (38)

Hard Tissue ('Bony') Impaction. This is where the wisdom tooth fails to erupt due to being obstructed by the overlying bone. This can be sub-divided into Partial and Complete Bony Impactions. (38)

Partial Bony. The superficial portion of the tooth is covered only by soft tissue but the height of the tooth's contour is below the level of the surrounding alveolar bone. Apart from cutting the gingiva (gum) & possible bone removal from behind the tooth, the tooth's roots may need to be divided. (38)

Complete Bony. The tooth is completely encased in bone so that when the gingiva is cut and reflected back, the tooth is not seen. Bone removal (large amounts) together with root sectioning will be needed to remove the tooth. These are often the most difficult tooth to remove. (38)
2) Winter's Classification \(^{38, 39}\)

Winter's classification is based on the inclination of the impacted third molar tooth to the long axis of the adjacent second molar tooth \(^{38}\). The method used by Winter to assess the relationship of the third molar tooth to the mandibular canal depends on the angulations of the third molar tooth which could be mesioangular, distoangular, horizontal or vertical.

![Winter's Lines Diagram](image)

**Figure 2. Winters Classification of third molar impaction \(^{38}\)**

**WINTER’S LINES**

The winter’s lines are three imaginary lines (red, amber and white) drawn on an orthopantagrapgh (OPG) radiograph to determine the position and depth of the mandibular third molar tooth.

- The white line is drawn along the occlusal surfaces of the erupted mandibular molars and extended over the third molar posteriorly. It indicates the difference in occlusal level of the first and second molars the third molar.
- The amber line represents the height of the bone or the bone level. The amber line is drawn from the surface of the bone on the distal aspect of the third molar or from the ascending ramus to the crest of the inter-dental septum of the first and second molars. This line denotes the margin of the alveolar bone covering the third molar and gives some indication to the amount of bone that will need to be removed for the tooth to come out.
- The red line is an imaginary line drawn perpendicular from the amber line to an imaginary point of application of an elevator. This is usually the mesial cemento-enamel junction for a mesio-angularly impacted third molar tooth, distal cemento-enamel junction for a disto-angularly impacted third molar tooth, mesial cemento-enamel junction for a horizontally impacted third molar tooth and buccal cemento-enamel junction for a vertically impacted tooth.
The red line indicates the amount of bone that will have to be removed before elevation of the tooth and so the depth of impaction of the tooth within mandible and the difficulty encountered in removing the tooth. With each increase in length of the red line by 1mm, the impacted tooth becomes three times more difficult to remove. (Howe and Poyton, 1960) If the red line is less than 5mm then the tooth removal is easy, whereas if the red line is greater than 5mm then the tooth removal is difficult.

Figure 3 Winter’s Classification

The method of judging the depth of the third molar is to divide the root of the second molar into thirds. A horizontal line is drawn from the point of application for an elevator to the second molar. If the point of application is adjacent to the coronal, middle or apical root third, then the tooth extraction is assessed as easy, moderate or difficult respectively. The drawback of this method is that whilst it indicate the depth of impaction and therefore an indication of the extend of difficulty, it does not indicate the relative relationship of the third molar roots and it’s proximity to the neurovascular bundle. (40)

3) Pell & Gregory's Classification (38, 41)

This is based on the relationship between the impacted mandibular third molar tooth to the ramus of the mandible and the mandibular second molar tooth (based on the space available distal to the mandibular second molar tooth).

- **Class A** - The occlusal plane of the impacted tooth is at the same level as the occlusal plane of the second molar. The highest portion of the impacted third molar is on a level with or above the occlusal plane.

- **Class B** - The occlusal plane of the impacted tooth is between the occlusal plane and the cervical margin of the second molar. The highest portion of impacted third molar is below the occlusal plane but above the cervical line of the of the second molar.

- **Class C** - The impacted tooth is below the cervical margin of the second molar. The highest portion of the impacted third molar is below the cervical line of the of the second molar.
• **Class 1** - There is sufficient space available between the anterior border of the ascending ramus and the distal aspect of the second molar for the eruption of the third molar.

• **Class 2** - The space available between the anterior border of the ramus and the distal aspect of the second molar is less than the mesio-distal width of the crown of the third molar. It denotes that the distal portion of the third molar crown is covered by bone of the ascending ramus.

• **Class 3** - The third molar is totally embedded in the bone of the anterior border of the ascending ramus because of the absolute lack of space. It is obvious that Class 3 teeth present more difficulty in removal as a relatively large amount of bone has to be removed and there is a risk of damaging the inferior alveolar nerve or fracturing the mandible or both.

![Pell & Gregory Classification of 3rd Molar Impactions](image)

**Mandibular Branch of the Trigeminal Nerve, normal anatomy and variation.**

The Mandibular Nerve, which originates at the trigeminal ganglion, is the largest of the three divisions of the Trigeminal Nerve. The posterior trunk of the Mandibular Nerve branches into Auriculotemporal, Lingual and Inferior Alveolar Nerves in the infratemporal fossa. (42)

**The mandibular canal**

The Inferior Alveolar Nerve enters the mandibular canal through the mandibular foramen on the medial surface of the ascending mandibular ramus, along with the Inferior alveolar artery, the inferior alveolar vein and the inferior alveolar lymphatic vessels and together they are called the inferior alveolar neurovascular bundle. (42) The artery lies parallel to the nerve as it traverses anteriorly, but its position often varies with respect to being superior to the nerve within the mandibular canal. (42) The inferior alveolar vein lies superior to the nerve and there may often be multiple veins. (42) The mandibular canal containing this neurovascular bundle runs obliquely downward and forward in the ramus, and then horizontally forward in the body till the mental foramen. As it runs anteriorly, the mandibular canal carrying the neurovascular bundle, gradually crosses from a lingual to a more buccal plane. Craniocaudal and buccolingual position and branching pattern of the mandibular canal, however, differ within the mandibular body. (42)
The mandibular canal when proximal to the third molar region, is usually a single large structure, 2.0 to 4.0 mm in diameter. The neurovascular bundle is generally well protected within the mandibular canal, however may have areas of perforation and exposure where roots of the mandibular teeth are in contact with the canal in the third molar region. The relative position of the mandibular canal to the mandibular third molar roots may be observed in a coronal plane as buccal, lingual, inferior or interradicular, and furthermore this may be with or without contact in relation to the roots.

<table>
<thead>
<tr>
<th>Contact: NO bone tissue between mandibular canal and third molar</th>
<th>Lingual</th>
<th>Interradicular</th>
<th>Buccal</th>
<th>Inferior</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Contact: bone tissue between mandibular canal and third molar</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Figure 5 Classification of the position and relationship of the third molar root (yellow) to the mandibular canal (red), as seen on coronal CBCT images.

Figure 6 Radiograph. The neurovascular bundle, appears radiographically as a dark ribbon of radiolucency flanked by two radiopaque white lines, the superior and inferior cortical lines. These cortical lines, represent the walls of the mandibular canal housing the neurovascular bundle. The radiographic appearance of both the superior and inferior cortical lines and their anatomic variations near the mandibular third molar teeth have been studied extensively by many researchers and have been the basis of pre-operative radiographic evaluation of the relative position of the mandibular canal to the mandibular third molar roots prior to surgery.

The mandibular canals are usually, but not invariably, bilaterally symmetrical, and the majority of hemi-mandibles contain only one major canal. There may also be duplication or division of the canal, known as bifid canals. Where this duplication of the mandibular canal occurs near the mandibular third molar roots, additional challenges are posed in the pre-
operative evaluation of the relative positions of these canals to the mandibular third molar roots. The bifid canals may lie close to each other or lie separated and well apart from each other. The variable position of these bifid canals to each other and the root(s) of the mandibular third molar tooth then poses difficult challenges to the surgeon in the pre-operative evaluation of the relationship of the root(s) and the bifid canals on a two dimensional panoramic film. A two dimensional panoramic film is limited with the inability to provide a coronal, axial or sagittal view of the canal(s) or the root(s), and so the relative position to each other. On an OPG radiograph, the surgeon is reliant on radiographic signs to be made aware that there is an intimate relationship without knowing the relative position or depth perception.

The inferior Alveolar Nerve has two terminal branches, the Mental Nerve and the incisive Nerve. The inferior alveolar nerve is a sensory nerve innervating all the lower teeth and much of the associated labial gingivae, as well as the mucosa and skin of the lower lip and skin of the chin. Damage to the inferior alveolar nerve will result in altered sensation to the lower teeth, associated labial/buccal gingivae, as well as the mucosa and skin of the lower lip and skin of the chin.
Inferior Alveolar Nerve Complications

During the surgical removal of the mandibular third molar tooth, the surgeon may be alerted to the proximidity of the instruments to the inferior alveolar nerve initially by light bleeding when the inferior alveolar vein is disturbed and perforated then by more serious and intense pulsatile bleeding when the inferior alveolar artery is disturbed and perforated.\(^9\)

Altered sensation to the IAN following mandibular third molar surgery may arise from:

- **Stretch injury**, where the nerve may be intimately associated or entangled with the root and be stretched as the root is elevated out. This usually occurs where there may be a hooked root and the nerve is positioned within the inner curvature of the hook or where the nerve maybe be partially or completely trapped between two or more roots (interradicular).

- **Crush injury**, where the nerve maybe intimately associated with the tooth root and maybe crushed as the root is mobilised during elevation. The nerve may even be entrapped between the tooth root and alveolar bone, making it vulnerable to crush injury. This may occur on the lingual side or buccal side of the root(s) or even interradicular.

- **Laceration (complete or partial)**, where the nerve may be inadvertently lacerated or severed by the bur used to gutter bone and section roots. Likewise, an exposed nerve maybe lacerated partially or completely by inappropriate instrumentation techniques.

These injuries need not always be the direct result of instrumentation and breach of the mandibular canal, and may even be inadvertently caused by sharp bone or tooth fragments dislodged into the mandibular canal indirectly during instrumentation.

Inflammation is a direct result of any trauma (surgical included) and results in a build up of oedema and pressure within an enclosed space (of the alveolar canal) involving the inferior alveolar nerve. As there is no opportunity for expansion the oedema will lead to an increase in pressure around the nerve with an associated loss or decrease in neural transmission. The patient will then perceive an altered sensation to the lip, chin and related teeth. With resolution of the inflammation, and hence reduced pressure on the neural structures, the altered sensation to the lip, chin and related teeth is also likely to resolve. Similarly a Persistent altered sensation is likely related to direct trauma to the neurological structures, which may or may not resolve with time.

Permanent injury to the inferior alveolar nerve occurs in less than 1% of cases, but temporary and therefore less serious injury is seen in 0.6% to 5.3%.* It is possible to predict the risk of inferior alveolar nerve injury dependent on the degree of intimacy in anatomical relationship between the impacted tooth and the inferior alveolar nerve.\(^3\)

Neurosensory deficit, when present, is considered temporary if it resolves within 6 months. However, if the deficit persists more than two years, the altered sensation is considered to be permanent.\(^9\)

Any loss of normal function of a sensory nerve is highly significant. The degree to which this is the case is reflected in the way the English language uses various terms to describe the nuances of this loss.

* The variable range in the incidence of paresthesia in this reference \(^3\) and earlier reference \(^2\) in the background information page 3 is due to differences in the literature that was reviewed by the authors. However, the incidence of nerve injury is entirely relevant to the study and this is highlighted as an important factor here.
Terms of neuropathy associated with peripheral nervous system:

- **Allodynia** - Perception of an ordinarily non-noxious stimulus as pain
- **Analgesia** - Absence of pain perception
- **Anesthesia** - Absence of all sensation
- **Anesthesia dolorosa** - Pain in an area that lacks sensation
- **Dysesthesia** - Unpleasant or abnormal sensation with or without a stimulus
- **Hypalgesia (hypoalgesia)** - Diminished response to noxious stimulation (eg, pinprick)
- **Hypoesthesia** - Diminished response to mild stimulation
- **Hyperalgesia** - Increased response to noxious stimulation
- **Hyperesthesia** - Increased response to mild stimulation
- **Hyperpathia** - Presence of hyperesthesia, allodynia, and hyperalgesia usually associated with overreaction, and persistence of the sensation after the stimulus
- **Hypesthesis (hypoesthesia)** - Reduced cutaneous sensation (eg, light touch, pressure, or temperature)
- **Neuralgia** - Pain in the distribution of a nerve or a group of nerves
- **Paresthesia** - Abnormal sensation with or without a stimulus
- **Radiculopathy** - Functional abnormality of one or more nerve roots

**Classification of Nerve Injury** is important in a clinical setting as it allows the surgeon to discuss the outcome with the patient together with a likely outcome scenario. As it is impossible to anticipate the outcome initially (unless the surgeon is aware that the nerve has been severed) time is the main mechanism by which the type of injury is classified.

Nerve injuries have been classified by both Sunderland\(^{45}\) and Seddon.\(^{46}\)

In 1943, Seddon\(^{46}\) has described three types of nerve injury which are of particular significance to the inferior alveolar nerve:

- **Neurapraxia** is a mild, temporary injury often caused by compression or retraction resulting in temporary conduction block (sensory loss, motor weakness). Spontaneous recovery usually occurs within four weeks or less.

- **Axonotmesis** is a more significant injury, where there is disruption or loss of continuity of some axon which undergo wallerian degeneration distal to the site of injury. There is prolong conduction failure and initial signs or symptoms of recovery of nerve function do not appear for 1 to 3 months after injury.

- **Neurotmesis** is complete severance or internal physiological disruption of all layers of nerve. There is a total permanent conduction block of all impulses (paralysis, anaesthesia) and no recovery is expected without surgical intervention.
In 1951, Sunderland\textsuperscript{[45]} expanded Seddon’s classification to five degrees of peripheral nerve injuries:

- First degree, same as Seddon’s Neurapraxia
- Second degree, same as Seddon’s axonotmesis
- Third degree, is a nerve fibre interruption, where there is a lesion of the endoneurium, but the epineurium and the perineurium remain intact. Recovery is possible with surgical intervention.
- Fourth degree, where only the epineurium remains intact and surgical repair is required.
- Fifth degree, where there is a complete transection of the nerve, complete recovery may not be possible.

The table below gives a summary of both classifications, along with the associated injury and recovery potential:

<table>
<thead>
<tr>
<th>Sunderland</th>
<th>Seddon</th>
<th>Injury</th>
<th>Recovery Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Neuropraxia</td>
<td>Ionic block; possible segmental demyelination</td>
<td>Full</td>
</tr>
<tr>
<td>II</td>
<td>Axonotmesis</td>
<td>Endoneurial tube intact</td>
<td>Full</td>
</tr>
<tr>
<td>III</td>
<td>Axonotmesis</td>
<td>Endoneurial tube torn</td>
<td>Slow; incomplete</td>
</tr>
<tr>
<td>IV</td>
<td>Only epineurium intact</td>
<td>Neurona-in-continuity</td>
<td>None</td>
</tr>
<tr>
<td>VI</td>
<td>Neurotmesis</td>
<td>Combination of above</td>
<td>Unpredictable</td>
</tr>
</tbody>
</table>

Table 1, Nerve Injury Classification \textsuperscript{[45, 46]}

Permanent and irreversible damage to the inferior alveolar nerve may result in neuropathic pain and permanent life long disablement to the patient\textsuperscript{[47-49]} When a sensory nerve is damaged there is pain, altered sensation and numbness. The pain may manifest in the form of hyperaesthesia, allodynia or hyperalgesia. The altered sensation may manifest in the form of paraesthesia or dysesthesia. Numbness may manifest in the form of hyperaesthesia. Consequences for the patient may be permanent life long disablement\textsuperscript{[47, 49]} Functional disablement includes eating, speaking, drinking, sleeping, kissing, make-up, shaving, tooth brushing, etc. Chronic pain is pain that extends beyond the normal expected period of healing, and so such pain can have extensive psychological disablement which may also affect the chronic pain sufferers with depression, anger, post traumatic stress disorder, feeling of victimized and loss of trust. The consequences of nerve damage not only include emotional and psychological trauma to the patient, but there may be medico-legal ramification and subsequent costs to the profession, institution and the community\textsuperscript{[47-49]}

These list of morbid states following neurological damage emphasizes the severity of any neurological complication. Hence the avoidance or minimization of any trauma to the Inferior Alveolar Nerve requires an understanding of the preexisting relationship of the inferior alveolar nerve to the roots of the mandibular third molar teeth. \textsuperscript{[3]}
Careful pre-operative evaluation of the relative relationship of the mandibular canal to the mandibular third molar roots will play a particular role in influencing the outcome of the mandibular third molar surgical procedure.\(^3\)

The relative position of the mandibular canal to the mandibular third molar roots have been investigated extensively over the years.\(^{12, 15, 16}\) The findings have influenced pre-operative evaluation techniques and methods, therefore the surgical treatment planning. This is reflected in the type of mucoperiosteal flap designed, amount of bone removal required and the tooth sectioning technique utilised. Radiographic imaging is seen as the main pre-operative evaluation technique in identifying and predicting the path of the inferior alveolar nerve, and so the relative position with the mandibular third molar roots.
Literature Review

Predictable surgical outcome and prevention can be achieved with appropriate imaging and surgical treatment planning.

When there is an intimate relationship between the third molar roots and the mandibular canal then surgical removal of this tooth may cause damage to the inferior alveolar nerve generally resulting generally in either paresthesia or dysaesthesia. Several studies have assessed the radiographic predictors of potential nerve injury. Panoramic radiography (orthopantomograph) has been recommended as the primary radiographic investigation of choice in preoperative assessment of mandibular third molar teeth and the surrounding structures.\cite{12, 15, 16}

Orthopantomograph (OPG)

OPG is the initial radiographic assessment of choice and in most instances it may be the only image required to perform the surgical procedure. It is a two dimensional panoramic representation of the maxilla and the mandible, the associated intra-bony structures and the dentition, and is taken with a relatively low radiation dosage.\cite{17} On the other hand, computerised tomographs (CTs) provides a three dimensional representation of the same area of interest, and so more useful information about the relative position of these structures of interest to each other and therefore provide better perception of the depth to approach surgically.\cite{17} The downside of computerised tomography is the relatively high radiation dosage the patient is subjected to during each scan compared to OPG radiographs. CT scanners require large capital outlay with the initial purchase and subsequent running costs. The scanners are large and require large space for housing, appropriate room modifications to accommodate radiation safety requirements. Additionally, highly trained radiographers are required for the acquisition of the DICOM (Digital Imaging and Communications) data set and the conversion of this by digital manipulation into clinically relevant images. The OPG scanners have cheaper associated running costs than CT machines, requiring less technical skill to operate and generate clinically relevant images. Additionally, OPG scanners are smaller and more practical in a dental practice setting.

Figure 7, The mandibular canal is identified radiographically by the radiopaque superior and inferior cortical lining.
Figure 8. The mandibular canal is identified radiographically by the radiopaque superior and inferior cortical lining.

The relative relationship and proximidity of the mandibular third molar roots to the inferior alveolar canal can be predicted by several radiographic signs. (12, 15)

1. Darkening of the roots (12, 15) (Figure 9)
2. Deflected roots (12, 15) (Figure 10)
3. Narrowing of the root (12, 15) (Figure 11)
4. Dark and bifid roots (12, 15) (Figure 12)
5. Interruption of white line(s) (12, 15) (Figure 13)
6. Diversion of the inferior alveolar canal (12, 15) (Figure 14)
7. Narrowing of the inferior alveolar canal (12, 15) (Figure 15)

Rood and Shehab (15) evaluated the reliability of these radiographic signs as predictors of likely nerve injury through retrospective and prospective survey of 1560 impacted mandibular third molars requiring surgical removal. (15) In order of frequency, diversion of the canal, darkening of the root and interruption of the white line were found to be significantly related to inferior alveolar nerve injury in both studies.

A review of the literature by Rood and Shehab (15) reveals that seven radiological signs have been suggested as indicative of a close relationship between the mandibular third molar tooth and the inferior alveolar canal. (15) Four of these signs are seen on the root of the tooth and the other three are changes in the appearance of the inferior alveolar canal. (15)
1. **Darkening of the root** ([12, 15]) (Figure 9)

Usually the density of the root is the same throughout its length and this is not disturbed when the images of the tooth and inferior alveolar canal overlap. When there is impingement of the canal on the tooth root, there is loss of density of the root (Fig. 9); the root appears darker (Main, 1938; [12, 15] Miles & West, 1954; [12, 15] Durbeck, 1957; [12, 15] Seward, 1963; [12, 15] Killey & Kay, 1975; [12, 15] Kipp et al., 1980; [12, 15] Howe, 1985). Howe and Poyton (1960) ([12, 15]) reported that 93.1% of the teeth in true relationship to the canal showed this sign. Darkening of the root is attributed to the decreased amount of tooth substance or loss of the cortical lining of the canal between the source of X-rays and the film (MacGregor, 1976). ([12, 15])

2. **Deflected roots** ([12, 15]) (Figure 10)

Deflected roots or roots hooked around the canal are seen as an abrupt deviation of the root, when it reaches the inferior alveolar canal. The root may be deflected to the buccal or lingual side or to both sides so that it may completely surround the canal (Stockdale, 1959); ([12, 15]) or it may be deflected to the mesial or distal aspect (Waggener, 1959). ([12, 15])
3. Narrowing of the root (12, 15) (Figure 11)

Seward (1963) (12, 15) stated ‘If there is narrowing of the root where the canal crosses it, it implies that the greatest diameter of the root has been involved by the canal, or that there is deep grooving or perforation of the root’.

4. Dark and bifid root (12, 15) (Figure 12)

This sign appears when the inferior alveolar canal crosses the apex and is identified by the double periodontal membrane shadow of the bifid apex (Seward, 1963). (12, 15)
5. Interruption of the white line(s) \citep{12, 15} (Figure 13)

The white lines are the two radio-opaque lines that constitute the ‘roof’ and ‘floor’ of the inferior alveolar canal. These lines appear on a radiograph due to the rather dense structure of the canal walls (Durbeck, 1957). \citep{12, 15} The white line is considered to be interrupted if it disappears immediately before it reaches the tooth structure; either one or both lines may be involved (Howe & Poyton, 1960; \citep{12, 15} Killey & Kay, 1975; \citep{12, 15} MacGregor, 1976; \citep{12, 15} Kipp et al., 1980; \citep{12, 15} Rud, 1983). \citep{12, 15} The interruption of the white line(s) is considered to indicate deep grooving of the root if it appears alone or perforation of the root if it appears with the narrowing of the inferior alveolar canal (Seward, 1963; \citep{12, 15} Howe, 1985). \citep{12, 15} The interruption is considered by some to be a ‘danger sign’ of a true relationship between tooth root and canal (Summers, 1975). \citep{12, 15}

6. Diversion of the inferior alveolar canal \citep{12, 15} (Figure 14)

The canal is considered to be diverted if, when it crosses the mandibular third molar, it changes its direction (Fig. 14), (Miles & West, 1954; \citep{12, 15} MacGregor, 1976; \citep{12, 15} Kipp et al., 1980; \citep{12, 15} Rud, 1983a). \citep{12, 15} Seward (1963) \citep{12, 15} attributed an upward displacement of the inferior alveolar canal to the contents of the canal passing through the root and hence, during eruption of the third molar, the contents are dragged upwards with it. Rud (1983a) \citep{12, 15} reported a 1% incidence of an upward deflection of the canal where it overlapped the root and 4% when the root was grooved.
7. Narrowing of the inferior alveolar canal\(^{12,15}\) (Figure 15)

The inferior alveolar canal is considered to be narrowed if, when it crosses the root of the mandibular third molar, there is a reduction of its diameter (Fig. 15) \(^{(12,15)}\) (Poyton, 1982). \(^{(12,15)}\) This narrowing could be due to the downward displacement of the upper border of the canal (Kipp et al., 1980; \(^{(12,15)}\) Rud, 1983a); \(^{(12,15)}\) or the displacement of the upper and lower borders toward each other with the hourglass appearance (Cogswell, 1942; \(^{(12,15)}\) Rud, 1983a). \(^{(12,15)}\) The hourglass form indicates a partial encirclement of the canal (Seward, 1963; \(^{(12,15)}\) MacGregor, 1976) \(^{(12,15)}\) or a complete encirclement (Waggener, 1959; \(^{(12,15)}\) Killey & Kay, 1975; \(^{(12,15)}\) Stimmers, 1975; \(^{(12,15)}\) Howe, 1985); \(^{(12,15)}\) or it may mean either of these alternatives (Cogswell, 1942; \(^{(12,15)}\) Austin, 1947; \(^{(12,15)}\) Miles & West, 1954; \(^{(12,15)}\) Uotila & Kilpinen, 1968). \(^{(12,15)}\) Howe and Poyton (1960) \(^{(12,15)}\) reported 33.7% of teeth in a true relationship with the canal to have this sign.

Rood and Shehab (1990) \(^{(15)}\) considered the three most important radiologic signs in relation to surgical complications related to the inferior alveolar nerve were:

1) diversion of the inferior alveolar nerve;
2) darkening of the roots; and
3) deflection of the root apices by the canal

These were accepted as the most significant in predicting neurologic injury and were used in assessing the likelihood of damage to the inferior alveolar nerve. They also formed the basis for obtaining consent from the patient particular to realistic risk of damage of the nerve and subsequent mental anesthesia. The age of the patient and the local blood supply were considered additional factors relevant to nerve injury and subsequent recovery. Earlier studies have also highlighted that unerupted, deeply impacted, and horizontally placed lower third molar teeth are at highest risk of inferior alveolar nerve injury. \(^{(12,15,16)}\)

In a later study, Sedaghatfar et al (2005) \(^{(13)}\) stated that there were four radiographic signs on an OPG which were more significantly related to inferior alveolar nerve exposure. These are,

- darkening of the tooth root,
- narrowing of the tooth root,
- interruption of the white lines, and
- diversion of the canal.

The surgeon’s experience and overall estimate of the relative risk based on the panoramic
radiograph was also stated to have been statistically significant.\textsuperscript{(13)}

It is known that the risk dramatically increases when there is direct contact between the nerve and the tooth root. Thus, it is important to evaluate the topographic relationship between the mandibular canal and impacted third molars preoperatively.\textsuperscript{(1)} The prediction of close proximity of the inferior alveolar nerve to the roots of the mandibular third molar relies mainly on radiographic analysis.

**Limitations of OPG in assessment for third molar surgery:**

1. Limited depth of view.
2. Superimposed structures.
3. Distorted structures with positioning errors.

In using OPG alone as a pre-operative diagnostic tool it is always difficult to know the exact relationship of the IAN to the mandibular third molar tooth, apart from knowing that the relationship is intimate. It may not be until the surgery has begun that the surgeon may become aware\textsuperscript{(3)} of the relationship when intraoperative clinical signs such as bleeding from the inferior alveolar vessels or exposure of the nerve to alert the surgeon to the proximity of the Inferior Alveolar canal. Smith\textsuperscript{(16)} states that intraoperative exposure of the inferior alveolar nerve increases risk of neurological damage by 15-fold, with a 20% risk of postoperative anesthesia. Because the inferior alveolar vein lies superior in the canal, significant bleeding alerts the surgeon that the canal has been breached and neurologic injury is a realistic sequel.\textsuperscript{(50)} More profuse bleeding usually indicates inferior alveolar arterial injury, which is intimately associated with the inferior alveolar nerve.

Other researchers (Tay and Go)\textsuperscript{(51)} have also reported that sighting an exposed intact inferior alveolar nerve bundle during third molar surgery indicates its intimate relationship with the third molar and carries a 20% risk of paresthesia, with a 70% chance of recovery by 1 year from surgery.

Hasegawa, et al,\textsuperscript{(52, 53)} reported that the exposure of the inferior alveolar nerve and the incidence of remarkable hemorrhage during extraction were both noted to be associated with an increase in inferior alveolar nerve damage. It has also been reported in other earlier studies, Gülicher et al,\textsuperscript{(54)} that postoperative hypoesthesia of the lower lip occurred nearly five times more frequently in cases where there was nerve exposure during extraction.\textsuperscript{(59)} It has been demonstrated that bleeding can result from disruption of the inferior alveolar nerve and therefore direct injury.\textsuperscript{(53)} However, indirect injury to the inferior alveolar nerve can also occur due to compression from postoperative swelling, or hemorrhage.\textsuperscript{(59)} In the study by Hasegawa, et al,\textsuperscript{(52, 53)} using multivariate analysis, they found that the exposure of the inferior nerve and the presence of remarkable hemorrhage during extraction were found to be associated with a higher risk of hypoesthesia than was alveolar nerve exposure alone. However, Valmaseda-Castellón, et al \textsuperscript{(55, 56)} have stated in their study that it is unclear whether hemorrhage is merely a consequence of disruption of the inferior alveolar nerve bundle or whether it has some other source and actually represents the cause of inferior alveolar nerve damage resulting from compression. Smith\textsuperscript{(19)} in his article has stated that temporary neurosensory deficit that ensues may often result from either direct injury from the tips of the third molar tooth or blood entering the enclosed bony canal and compressing the nerve. Whereas excessive bleeding is least likely with elevation alone, the incidence significantly increases when bone removal is used with additional techniques, i.e., tooth division and lingual split, but no one additional technique confers an increasing incidence of bleeding over another. The physical pressure of hemostatic agents, e.g., Surgicel\textsuperscript{(47, 57)} into the socket, although often an inevitable sequelae for “excessive” hemorrhage, appears to be associated with the highest risk (20%) of ID neurosensory deficit, albeit temporary.
Computed Tomography

How can this relationship be more accurately predicted?

When the panoramic image is suggestive of an intimate relationship between the impacted tooth and the mandibular canal, medical computer tomography (CT) has been previously recommended for further investigation to demonstrate the three-dimensional relationship between the 2 structures.\(^{(19, 23, 24)}\) However, one obvious drawback of medical CT is the much higher radiation dose that the patient receives compared with panoramic radiography.

![Typical Values of Effective Dose for Various Medical X-rays](image)

Figure 16 Australian Radiation Protection and Nuclear Safety Agency\(^{(58)}\)

Other drawbacks are access to the modality and the higher financial costs of the procedure. Orthopantagraphe scan are relatively cheap as the equipment is relatively cheap (ranging from $25000 to $150000) and not requiring specialized training for radiographers to operate and interpret the results of the scans. Standard OPG scan cost to the patient may range from ($50 to $150).* CT scans have a relatively high running cost as the equipment cost ranges from ($500,000 to $1,000,000 plus), and require specialized training for the radiographers to operate and interpret the results. Standard CT scan of the head and neck cost to the patient may range from ($150 to $500).*\(^{(59)}\)

* Fee range prior to medicare rebate. Medicare rebate may not be available to all patients. Some radiology centres may bulk bill their services whilst others may require co-payments. Medicare rebate is unavailable for CT referrals from General Dental Practitioners.
There are few studies that correlated CT findings with surgical results. Maegawa et al. in their study, found that the inferior alveolar nerve was exposed at extraction in only 7 of 23 cases in which direct contact between the mandibular canal and the tooth root was observed on medical CT, providing positive predictive value of 30% and sensitivity of 100%. These results may indicate that medical CT is not very accurate in predicting the nerve exposure. Tantanapornkul, et al in their study of CBCT found in predicting the exposure, the sensitivity and specificity were 93% and 77% for cone-beam CT, and 70% and 63% for panoramic images, respectively. Comparing the results of the study by Maegawa et al. with the results of the study by Tantanapornkul, et al. there is indication that it may be possible that cone-beam CT is more accurate than medical CT in assessing the relationship between the mandibular canal and the mandibular third molar roots. The study by Tantanapornkul, et al. does certainly indicate that Cone-beam CT was significantly superior to panoramic images in both sensitivity and specificity.

With the introduction of maxillofacial cone-beam CT (CBCT), three-dimensional images are becoming more readily available for use in dental applications. In some countries Cone-Beam Computed Tomography (CBCT) may be known as Cone-Beam Volumetric Tomography (CBVT). The two terms refer to the same technology and technique of acquisition of the data set. The major advantages of cone-beam CT include high spatial resolution and low radiation dose. Tantanapornkul, et al performed a prospective study to determine the reliability of cone-beam CT in assessing the topographic relationship between the mandibular canal and impacted third molars. This study evaluated the diagnostic accuracy of cone-beam CT in predicting neurovascular bundle exposure following impacted mandibular third molar extraction and compared it with that of conventional panoramic images. The study also investigated the presence or absence of direct contact between the tooth root and the canal contents, which was three-dimensionally evaluated, and used as the diagnostic criterion in predicting neurovascular bundle exposure. It was considered that direct contact was present when loss of bone tissue between the 2 structures was observed on all three sections. Panoramic images were evaluated for the presence or absence of the following four features, all of which had been reported in previous studies to be suggestive of close contact between the tooth root and the mandibular canal: (a) interruption of the mandibular canal wall, (b) darkening of the root, (c) diversion of the mandibular canal, and (d) narrowing of the root. Using these findings in their investigations, Tantanapornkul et al. tried to determine the optimal panoramic diagnostic criterion in predicting exposure. The four panoramic features, interruption of the mandibular canal wall, darkening of the root, diversion of the canal and narrowing of the root, were found in 62, 30, 15, and 5 cases, respectively. Using univariate logistic regression analysis, it was demonstrated that these four panoramic features were all correlated with neurovascular bundle exposure at extraction. Thus, these features, if used alone, could effectively predict the neurovascular bundle exposure.

However, multivariate analysis of these four features, as predictor variables, showed only one feature, the interruption of the mandibular canal wall, was a significant predictor of the neurovascular bundle exposure. These findings suggested that, if used in combination, the other three panoramic features may not significantly contribute to the prediction of the neurovascular bundle exposure.

The study by Tantanapornkul, et al concluded that cone-beam CT was significantly superior to panoramic images in predicting the neurovascular bundle exposure following impacted mandibular third molar extraction. This study confirmed the clinical usefulness of cone-beam CT for preoperative evaluation of impacted mandibular third molars.
Cone Beam Computed Tomography (CBCT), an example of its application

CBCT is a computer based technology utilising either Flat Panel Detectors or Charge Coupled Devices, where the scan is saved as a DICOM data set that can be then manipulated and viewed in different dimensions (axial, coronal or sagittal), as well panoramic. Three dimensional views of the maxilla and mandible can be created utilising associated software such as “Dolphin”.

![Figure 17, Pre-operative Orthopanatagaph](image)

The inferior alveolar canal is identified radiographically by the radiopaque superior and inferior cortical lining. In the case of the tooth 38, the inferior cortical line is traceable and appears diverted, whilst the superior cortical line is darkened and interrupted.

![Figure 18](image)

**Radiographic signs demonstrated on the pre-operative orthopantanograph**

Figure 18
Radiographic signs demonstrated on the pre-operative orthopantamograph

Figure 19

Radiographic signs demonstrated on the pre-operative orthopantamograph

Figure 20
Orthopantomograph, however, is limited by several factors, including:

1. Limited depth of view: Orthopantomograph represents a two dimensional view of three dimensional structures, and so is limited in providing the relative position of these structures to each other.

2. Superimposed structures: Other structures may be superimposed in a panoramic scan, creating a ghosting effect which may make it difficult to distinguish fine structures from each other.

3. Distorted structures with positioning errors: Panoramic imaging of three dimensional structures results in distorted views from the centre to the edge, and also a distorted relationship of these structures.

In a panoramic view derived from a CBCT scan, superimposed structures are eliminated and there are no distortion of structures.

Figure 21

There is still limitation with the depth of view, however, alternate planes of view can be generated from the data set of the single CBCT scan as demonstrated below of the coronal, axial and sagittal views. The interproximal contact point of adjacent teeth also appear very clearly, which may be useful for diagnosis of interproximal caries.

Figures 22.1, 22.2 and 22.3 (below left)  Figure 23 (below right)

Different planes of views achieved on a CBCT:
1. Coronal view
2. Axial view
3. Sagittal view

Disadvantage of CBCT is the greater radiation exposure and associated costs. However, as CBCT technology is evolving, the exposure of the patient to radiation with a CBCT scanner is approaching the same par as that of an OPG scanner, and in time it may make sense to rely solely on a CBCT as the initial imaging technique where more useful information is available at hand. This information need not be restricted to oral surgery, but can be useful in many fields of dentistry.
The Research Study

The purpose of this present study is to evaluate whether there is any difference in the incidence of inferior alveolar nerve complications with the use of the OPG alone or in combination with CBCT. This then would allow us to determine whether one method or the other provides the more predictable outcome following lower third molar surgery where there has been a close relationship of the roots to the inferior alveolar canal. The study compared the surgical outcomes for two groups of patients specifically looking at the incidence of paresthesia in 2005/2006 prior to CBCT compared to 2010/2011 when CBCT was widely used as a pre-operative diagnostic tool. Cone-Beam Computed Tomography became available as a diagnostic tool at Sydney’s Westmead Centre for Oral Health in 2006.

The outcome of the study will give a base to evaluate whether the cost of the technology and the exposure of the patient to additional radiation would be beneficial or not to the patient, the individual institution, the community and the profession.

Method

Retrospective study examined lower third molar cases that were surgically managed at Westmead Centre for Oral Health, Westmead NSW, between November 2005 to August 2006 and November 2010 to August 2011. The study involved examination of the pre-operative, operative and post-operative written records, as well as the OPG and relevant CBCT records.

The study was limited to mandibular third molar teeth requiring bone guttering, tooth sectioning or both. The data base of the ISOH system was searched for suitable cases based on procedures performed relating to item numbers 323 and 324, whereby the procedure required bone guttering, tooth sectioning or both. Item numbers 311, 314 and 322 were excluded as they represented procedures on teeth where no close relationship was likely to exist between the roots and the inferior alveolar nerve, and where post-operative complication with the inferior alveolar nerve was unlikely. In order to maintain the randomisation of the study, all cases that were treated under item numbers 323 and 324 were considered, irrespective of the type of relationship displayed between the roots and the inferior alveolar canal. Patients that were not able to communicate and describe altered sensations to the lip were excluded, however patients requiring translators were included as the clinicians were able to obtain feedback via the translators.

The study included patients that were treated either under local anaesthesia or intravenous sedation. Patients treated under General Anaesthesia were excluded as either the written records or the radiographic records were incomplete, missing or archived. Additionally, the general anaesthesia cases may have been assessed pre-operatively utilising helical beam CTs rather than CBCTs and therefore did not fall within the parameters of the study.

The study was divided into two groups, one where OPGs alone were utilised the second group had OPGs and CBCTs to assist the surgeon to formulate the pre-operative evaluation of the relative position of the mandibular canal to the mandibular third molar roots. All the OPG and CBCT images were taken at the dental radiography department of the Westmead Centre for Oral Health. The CBCT images were acquired utilising the iCAT scanner used by the department, and the Digital Imaging and Communications in Medicine (DICOM) data set was processed utilising the associated iCAT software. DICOM is a standard for handling, storing, printing, and transmitting information in medical imaging.
All treatment in the form of surgical intervention was carried out only at Westmead Centre for Oral Health, involving departments of exodontia, intravenous sedation and oral surgery, where internal and external referrals were accepted and managed accordingly.

The experience of the clinicians varied from supervised undergraduate students, recent graduates and experienced dental officers employed by WCOH, clinical tutors employed by the University of Sydney, OMFS registrars and OMFS consultants.

The minimum size of the groups was determined to be 250 based on the documented incidence of neurological complications following third molar surgery being 1.5% (range of 0.05-9%). It was assumed that as the WCOH was a teaching hospital the incidence of complications would be in the middle range.

As the study encompassed two different periods of time it was considered appropriate that data should be taken from a similar time of the year in both the first and second studies so as to reduce, as much as possible, the seasonal variations in surgical presentations.

The study was divided into two groups:

Group 1 consisted of records of patients treated prior to September 2006 at which time the OPG alone was utilised as a pre-operative diagnostic aid. Accordingly, any pre-operative evaluation that involved CT referrals were excluded. The time period chosen was November 2005 to August 2006. Total number studied 265.

Group 2 consisted of records of patients treated after the introduction of CBCT as a pre-operative diagnostic tool, where OPG was utilised as the primary view and if radiographic signs indicated then CBCT was used for additional views of the root relationship with the IAN. The similar time period chosen as for the first study, November 2010 to August 2011. Total number studied 325.

Ethics approval was sought through the Westmead Hospital Ethics Committee and was granted prior to commencement of the study. Accordingly, all records were de-identified and treated with strict confidence. Total number for groups one and two was 590.

The predetermined categories under which the data was collected included de-identification number, gender, age, dental record number, tooth number, eruption status, impaction classification, presenting complaint, radiographic signs determined on initial OPG radiograph, where applicable after 2006 whether CBCT was taken and where applicable the relative relationship of the IAN to the lower third molar roots, date of surgery, item numbers used, treatment department and clinician category, intra-operative finding, post-op complications, time to recover, where applicable accuracy of nerve tracing on CBCT, where applicable whether complications were predictable on a CBCT. The data collected were tabulated under these predetermined categories on an excel spread sheet. The completed data base as recorded on an excel spreadsheet is attached and labelled as Appendix 1.

Analysis

Age and gender, radiographic signs, CBCT relationship and post-op complications were all statistically analysed with IBM SPSS Statistics Software Version 20. The most relevant to this study the incidence of post-op complications, risk ratios, risk difference and numbers needed to treat were calculated using a two by two table.
Results

Total of 590 surgical cases were included in the study, with 265 in group one (prior to CBCT) and 325 in group two (following CBCT). Post-operative complications totaled 9, where group one had 6 and group two had 3. Numbers with no post-operative complications totaled 581, with 259 for group one and 322 for group two.

<table>
<thead>
<tr>
<th></th>
<th>Complication</th>
<th>No Complication</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment with OPG</td>
<td>6</td>
<td>259</td>
<td>265</td>
</tr>
<tr>
<td>Assessment with OPG + CBCT</td>
<td>3</td>
<td>322</td>
<td>325</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>581</td>
<td>590</td>
</tr>
</tbody>
</table>

Table 2, Two by two table

1. **Incidence of Complication only OPG**

\[
\text{Incidence} = \frac{\text{No of new complications}}{\text{Total number treated}} = \frac{6}{265} = 0.02264151 = 0.02 \text{ (rounded)}
\]

2. **Incidence of Complications with OPG + CBCT**

\[
\text{Incidence} = \frac{\text{No of new complications}}{\text{Total number treated}} = \frac{3}{325} = 0.00923077 = 0.01 \text{ (rounded)}
\]

3. **Risk Ratio of Complications**

\[
\text{Risk Ratio of Complications} = \frac{\text{Complications prior to CBCT}}{\text{Complications following CBCT}} = \frac{0.02264151}{0.00923077} = 2.45283005 = 2.45 \text{ (rounded)}
\]

Wald 95% CI: 0.619>2.453>9.715

4. **Risk Difference**

\[
\text{Risk difference} = \text{Complications prior to CBCT} - \text{Complications following CBCT} = 0.02264151 - 0.00923077 = 0.01341074 = 0.0134 \text{ (rounded)}
\]

5. **Numbers Needed to Treat (NNT)**

\[
\text{NNT} = \frac{1}{\text{Risk Difference}} = \frac{1}{0.01341074} = 74.5671006969041 = 75 \text{ (rounded to a whole number)}
\]

6. **Confidence Intervals**

As the smallest cell contained 3 cases the significance of the results was compromised (p=0.186) at a 95% confidence interval.
Conclusion

Using the two by two table drawn from the results and using the calculations outlined in the results, it can be concluded from the results that seventy five lower third molar surgeries are needed to be performed utilising CBCT as pre-operative diagnostic tools in order to reduce the incidence of inferior alveolar nerve complication by one.

<table>
<thead>
<tr>
<th>Numbers Needed to Treat (NNT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without CBCT</td>
</tr>
<tr>
<td>Risk</td>
</tr>
</tbody>
</table>

Table 3, Numbers Needed to Treat

Recovery Time

The recovery time for patients with altered IAN sensation was significantly reduced for Group 2. This result will have to be confirmed with a larger study. One possible explanation is that Group 2 have benefited from the additional information obtained from CBCT that was available to the clinician. This could be attributed to the ability of the clinician to radiographically visualize the intimate relationship of the mandibular third molar roots to the inferior alveolar nerve in different planes, including coronal, axial and saggital, as well as the ability to generate three dimensional computer generated reconstructions and nerve tracing from specifically designed software. Therefore it could be assumed with the benefit of CBCT imaging that all clinicians irrespective of experience were more careful when managing a case with particularly intimate preoperative relationship, and so minimising trauma to the nerve and in turn the recovery time.
Discussion

The purpose of this pilot study was to evaluate whether there was any difference in the incidence of inferior alveolar nerve complications when preoperative evaluation was carried out with the use of OPG alone or in combination of OPG with CBCT. Carrying out this pilot study as a retrospective study allowed the comparison of the data that was collected for each of the two groups during the course of normal clinical practice at a major public dental facility over two distinct past time periods, one before the introduction of CBCT with that of one after the introduction of CBCT. Neither the clinicians or the patients were aware of such a study at the time of the clinical procedures. This had meant that the preoperative evaluation for each subject and the surgical approach planned from the evaluation were not influenced with the knowledge of an impending study and so has not biased the outcome of the study or be influenced by confounding factors. Furthermore the setting of the study at The Westmead Centre for Oral Health (WCOH), a major public dental facility carrying out a range of dental procedures including oral surgical procedures, provided a good cross-section of patients with varying degrees of lower third molar impactions. Treatments for the two study groups in this pilot study were carried out in a range of departments within WCOH that carried out the same procedures of interest to the study. The treatment protocols and surgical set ups were consistent for all the departments and there were no inconsistencies that may have adversely influenced the treatment outcomes and biased the results. The treating practitioners were of varying experiences but consistent between the two groups. The two groups had similar numbers of practitioners. The varying experience did not have any bias impact as it allowed the study to test the consistency of the results between the two groups for varying experience over the two time periods. The less experienced practitioners may have benefited more from the additional CBCT information as it promoted more caution and care. Whilst the more experienced clinicians may have already prepared their clinical approach based on past experiences with similar cases. Irrespective of the experience of the clinician, the main benefit is the additional information provided by CBCT of the bucco-lingual relationship of the mandibular third molar roots to the IAN and the intimacy of this relationship neither of which are available on plain film OPG. All procedures within the predetermined parameters of item numbers 323 and 324 were included, and only excluded where post-operative follow up information that is key to the study were not available. The same time span was chosen for the two groups at the same time of the year but five years apart, therefore eliminating bias that may otherwise arise at two different times of the year where seasonal or social variations may influence attendance rates. The five years time span between the two groups was considered reasonable as there was no time overlap between the two groups, but treatment evaluation protocols and treatment techniques were kept consistent between the two groups. Other variable factors including gender, age, eruption status, impaction classification, presenting complaints, radiographic signs were all included, and so keeping the influence of these factors on the outcome of the study random. The outcome of the study did highlight the benefit of CBCT when used in combination with an OPG to verify the preoperative relationship of the lower third molar roots to the IAN. This pilot study demonstrates a trend where the incidence of altered nerve sensation had decreased for group 2 compared to group 1. It is possible that the clinicians were able to make better informed clinical decisions based on the additional knowledge available with CBCT, and carry out the procedure more carefully.

Confidence Interval significance

The figures obtained from the data collection were reasonable and significant to the initial purpose of the study, whether CBCT as a preoperative diagnostic tool was able to reduce the incidence of altered sensation to the IAN. The incidence of altered nerve sensation prior to CBCT was 1.5%, whilst the incidence of altered nerve sensation after CBCT was 0.9%. The significantly reduced incidence gives strength to the purpose of the study in proving that
Combining OPG and CBCT is a valuable preoperative diagnostic tool. This study has proven that using OPG and CBCT as preoperative diagnostic tools will reduce the incidence of altered sensation. The clinician and the patient can make more informed decision on whether to proceed with the treatment or not. The additional costs in delivering this type of treatment can now be justified as it benefits the patient in avoiding a psychologically and socially crippling side effect of the treatment, whilst eliminating a potential health risk in spread of infection and also severe pain or discomfort. This in turn will benefit the practitioner and the institution in terms of liability costs, whilst the community will benefit in a safer mode of treatment delivery.

The incidence of altered sensation in this research was too low to calculate a confidence interval. As the smallest cell contained three cases the significance of the results was compromised (p=0.186) at a 95% confidence interval. Longer retrospective study time period would also likely provide a similarly low figure, still making it difficult to calculate the confidence interval. Whether a confidence interval can be calculated from a cohort prospective study is yet to be determined and may not be known until the data from such a study are analyzed statistically. However, the low incidence of altered inferior alveolar nerve sensation is a positive reflection on the quality of care in a major public health care facility and one that is a teaching facility. In this regard the confidence interval is not significant to this study as the greatly reduced incidence of altered nerve sensation from 1.5% with OPG alone to 0.9% with OPG and CBCT is more significant to the purpose of this study.

**Overall benefit**

In this pilot study, the significance of CBCT and the risk versus benefit has been explored and the benefit highlighted. The numbers needed to treat (NNT) has been established in this study as 75 in order to have an overall benefit of one. Risks and benefits may be understood in terms of a minor benefit to a large number of people or a significant benefit to a few. This study has shown a significant benefit to a few, who may otherwise be debilitated with the third molar tooth pain as well as psychological and social scarring. The outcome of this study has given a base to evaluate whether the additional costs of the technology and greater exposure of the patient to additional radiation would be beneficial to the patient, the individual institution, the profession and the community at large. It is clear from reduced incidence of altered inferior alveolar nerve sensation between the two groups that there is overall benefit to the patient in eliminating the presenting pain complaint and as well avoiding a psychologically and socially crippling consequence to removal of a mandibular third molar tooth with a difficult presentation. Where indicated of a definitive nerve damage by CBCT pre-operative investigation, alternative treatment options may be chosen such as coronectomy which may eliminate a potential health risk such as spread of infection and severe pain or discomfort, without the imminent risk of a certain nerve damage. This in turn will benefit the practitioner and the institution in terms of liability costs, whilst the community will benefit in a safer mode of treatment delivery.

**Where to from here?**

This pilot study was carried out as a retrospective study and as such was focused on past procedures. The strength in this form of study is that we are investigating the results for past procedures based on two different pre operative investigation methods, and so able to determine whether CBCT was able to reduce the risk of nerve injuries and benefit patient management. The weakness in this form of study is that it is investigating pre-operative methods for past procedures only and not pre-operative methods which may be able to be varied and tested for future procedures. Retrospective studies can be easily influenced by bias and confounding factors to alter the results, whereas a prospective study is far less influenced by bias and confounding factors. Therefore, a prospective cohort study designed
to test the two pre-operative evaluation methods investigated in this pilot study would eliminate any bias and confounding factors and give this study strength and credibility. As there are ethics issues involved in clinically based study, new ethics approval would have to be sought, along with individual patient consent.

Future directions:

• Further similar studies may be able to compare findings from both retrospective and prospective studies from other facilities using other public dental service provider facilities with access to CBCT scanners. The broader studies would improve reliability of the results.

• As the technology behind CBCT is very dynamic, more scanners are emerging with varying capability and suitability of application in dentistry. Further investigations would benefit the patients and the profession in numerous ways for example: different scanner technologies, seeking diagnostic benefits with reduced radiation exposure.

• As the CBCT technology is very dynamic, so is the software systems behind the technology, including nerve tracing softwares. Accuracy and reliability of nerve tracing softwares are rapidly improving. The patients and clinicians both stand to benefit greatly from investigations of accuracy and reliability of these softwares available as pre-diagnostic tools.

Summary

To date the OPG examination remains the standard pre-operative examination. This is despite evidence that CBCT is significantly better, Tantanapornkul et al. It can be argued that the increase in radiation exposure to gain additional information is warranted if the CBCT is significantly better than OPG. Perhaps there is room for argument that CBCT will replace OPG in the future. This research shows that there is evidence to support the use of combined examination methods. Furthermore there is evidence that use of CBCT alone may soon have preference for initial pre-operative examinations.
References:


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