



Tara Renton

Prevention of Iatrogenic Inferior Alveolar Nerve Injuries in Relation to Dental Procedures

Abstract: This article aims to review current hypotheses on the aetiology and prevention of inferior alveolar nerve (IAN) injuries in relation to dental procedures. The inferior alveolar nerve can be damaged during many dental procedures, including administration of local anaesthetic, implant bed preparation and placement, endodontics, third molar surgery and other surgical interventions. Damage to sensory nerves can result in anaesthesia, paraesthesia, pain, or a combination of the three. Pain is common in inferior alveolar nerve injuries, resulting in significant functional problems. The significant disability associated with these nerve injuries may also result in increasing numbers of medico-legal claims.

Many of these iatrogenic nerve injuries can be avoided with careful patient assessment and planning. Furthermore, if the injury occurs there are emerging strategies that may facilitate recovery. The emphasis of this review is on how we may prevent these injuries and facilitate resolution in the early post surgical phase.

Clinical Relevance: It is imperative that dental practitioners are aware of the significant disability associated with iatrogenic nerve injuries and have an awareness of risk factors relating to inferior alveolar nerve injury. By understanding the risk factors and modification of intervention as a result, more of these injuries will be prevented.

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Trigeminal nerve injury is the most problematic consequence of dental surgical procedures with major medico-legal implications.¹ The incidence of lingual nerve injury has remained static in the UK over the last 30 years. However, the incidence of inferior alveolar nerve injury has increased, this being due to implant surgery and endodontic therapy.²

Iatrogenic injuries to the third division of the trigeminal nerve remain a common and complex clinical problem. Altered sensation and pain in the orofacial region may interfere with speaking, eating, kissing, shaving, applying make-up, toothbrushing and drinking, in

fact, just about every social interaction we take for granted.³ Usually after oral rehabilitation, the patient expects and experiences significant improvements, not only regarding jaw function, but also in relation to dental, facial, and even overall body image.⁴ Thus these injuries have a significant negative effect on the patient's quality of life and the iatrogenesis of these injuries lead to significant psychological effects.⁵

With regard to lingual nerve injuries related to third molar surgery, most patients recover normal sensation without treatment, but those with permanent deficits often have severe disability, as indicated by the high proportion of lawsuits in such cases.⁶ More than half of lawsuits are associated with lack of pre-operative informed consent for implant surgery, and most are associated with premolar implants, with up to 20% of patients undergoing microsurgery for ablation of a neuroma, reanastomosis or neural decompression.⁷ Legal proceedings were initiated by 33

(20%) of the 165 patients and the patients who initiated lawsuits were younger, more likely to have experienced anaesthesia, and more likely to have needed microsurgery.¹

Interestingly, few patients with permanent inferior alveolar nerve (IAN) injury resulting from orthognathic surgery or trauma present with significant complaints and this may, in part, be due to the clear pre-surgical consent and information, along with the significant perceived benefits of the surgery.⁸

Increasingly, complaints received by the GDC and ADA are implant related. In the UK, inferior alveolar nerve or lingual nerve neuropathy caused by dental surgery may result in claims of up to £20K for general damages, depending on the injury. Of claims made against the American Dental Insurance companies (Fortress and OMSNIC), 34% of patients were unhappy with the aesthetics and 24% of claims were related to nerve injury. Twenty four percent of oral surgery dental implant claims had an average payment of \$89,000 per patient

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while 37% of the general dental implant claims had an average payment of \$63,000 (Eastabrooks L, personal communication). Implant nerve injuries average payouts were higher than the average payout for IAN injury related to third molar surgery in the US. Interestingly, with implants cases in the USA there are increased claims against oral surgeons compared with general dentists. This may reflect the increased complexity of cases and the greater volume of dental surgery done by oral surgeons.

Mistaken assumptions include that the lingual nerve and inferior alveolar nerve injuries are similar and that lingual nerve injuries in association with lingual access third molar surgery are mainly temporary, with 88% of lingual nerve injuries resolving in the first 10 weeks post surgery.^{9,10} In contrast, the IAN is at more risk from a variety of dental procedures and the IAN is contained within a bony canal, predisposing it to ischaemic trauma and subsequent injury. This may also result in a higher incidence of permanent damage for inferior alveolar nerve injuries.

Causes of inferior alveolar nerve injury include:

- Local anaesthetic injections;
- Third molar surgery;
- Implants;
- Endodontics;
- Ablative surgery;
- Trauma; and
- Orthognathic surgery.

The inferior alveolar nerve (IAN) neuropathy related to third molar surgery or inferior dental block injections (IDBs) is usually temporary but can persist and become permanent (at 3 months). There are rare reports of resolution of implant-related IAN neuropathies at over 4 years,¹¹ but these do not comply with normal reports of peripheral sensory nerve injuries.¹² Many authors recommend referral of injuries after 6 months,¹³ but this may be too late for many other peripheral sensory nerve injuries. We now understand that, after 3 months, permanent central and peripheral changes occur within the nervous system, subsequent to injury, that are unlikely to respond to surgical intervention.¹⁴

Local analgesic-related trigeminal nerve injuries

Injuries to inferior alveolar and

lingual nerves are caused by local analgesia block injections and have an estimated injury incidence of between 1:26,762 to 1/800,000. Reports of incidences include 1:588,000 for Prilocaine and 1/440,000 for Articaine IAN blocks which is 20–21 times greater than for Lidocaine injections.^{15,16} Perhaps every full-time practitioner will find that he/she has one patient during his or her career who has permanent nerve involvement from an inferior alveolar nerve block and there is no means of prevention.¹⁵ These injuries are associated with a 34%¹⁵ and 70%² incidence of neuropathic pain, which is high when compared with other causes of peripheral nerve injury.

Recovery is reported to take place at 8 weeks for 85–94% of cases.¹⁷ IAN injuries may have a better prognosis than lingual nerve injuries and, if the duration of nerve injury is greater than 8 weeks, then permanency is a risk. However, the true incidence is difficult to gauge without large population surveys. The problem with these injuries is that the nerve will remain grossly intact and surgery is not appropriate as one cannot identify the injured region. Therefore, the most suitable management is for pain relief if the patient has chronic neuropathic pain.² A recent settlement of US\$1.4 million dollars (Maine, USA) for lingual nerve injury caused by local analgesic IAN block highlights the recognition of the associated disability and social repercussions of these injuries.

In the US, liability claims and malpractice suits are inherent risks associated with iatrogenic nerve injury⁶ and the reasons for avoidance of such injury are obvious. Iatrogenic nerve lesions may produce symptoms ranging from next to nothing to a devastating affect on quality of life. Only few studies, however, describe the range of neurosensory disturbance in terms of signs and symptoms related to impaired nerve conduction and neurogenic affliction,¹⁸ and there is a need for better standardization and documentation of sensory deficits resulting from nerve injuries and their recovery.¹⁹ Owing to the incidence of nerve injuries in relation to dental anesthesia, warning patients is not considered routine and, indeed, in the UK these iatrogenic injuries are not considered to be negligent. But recent evidence may question the use of high concentration local anaesthetic agents for inferior dental blocks

and may change this stance.

Nerve injury due to LA is complex. The nerve injury may be physical (needle, compression due to epineural or perineural haemorrhage) or chemical (haemorrhage or LA contents). Thus the resultant nerve injury may be a combination of peri-, epi- and intra-neural trauma causing subsequent haemorrhage, inflammation and scarring resulting in demyelination (loss of nerve lining).²⁰ There may be elements of direct mechanical trauma by the needle,²⁰ which has been the focus of most papers (no matter what type of bevel or indeed the method used for LA application!). Some authors infer that the direct technique involving 'hitting' bone before emptying cartridge and withdrawal of needle may cause additional bur deformation at the needle tip, thus 'ripping' the nerve tissue.²⁰ Only 1.3–8.6% of patients get an 'electric shock' type sensation on application of an IAN block and 57% of patients suffer from prolonged neuropathy, having not experienced the discomfort on injection, thus this is not a specific sign. Also, 81% of IAN block nerve injuries are reported to resolve at 2 weeks post injection.¹⁸

Chemical nerve injury may also be related to specific chemical agents²¹ and the LA components (type of agent, agent concentration, buffer, preservative). The variety of local anaesthetics available in the UK include; 2% Lidocaine, 2% Mepivacaine, 3% Mepivacaine, 3% Prilocaine, 4% Prilocaine and 4% Articaine. It may be the concentration of the local anaesthetic agent that relates to persistent neuropathy, based on evidence provided in studies by Perez-Castro *et al*,²² where increasing concentration of local anaesthetic agent significantly affected the survival rate of neurones *in vitro*. Epidemiologically, several reports have highlighted the increased incidence of persistent nerve injury related to IAN blocks with the introduction of high concentration local anaesthetics (Prilocaine and Articaine both 4%). Haas and Lennon in 1995 reported that Articaine was causing 21 times more nerve injuries in Canada when compared with lower concentration drugs.¹⁶ Hillerup and Jensen¹⁸ reported similar findings in Denmark, Pogrel in the USA and more recently in Canada.²³

Articaine is an amide analgesic which was introduced to dentistry in

1998. However, Lidocaine (also an amide analgesic) remains the gold standard in the UK. Articaine has been the most widely used local analgesic in many countries for over 20 years.^{24,25} Articaine is said to have the following advantages:

- Low toxicity subsequent to inadvertent intravascular injection,²⁴ which may be due to the rapid breakdown to an inactive metabolite (articainic acid);
- Rapid onset of surgical analgesia (2.5 =/-1.1 minutes) compared with conventional Lidocaine;²⁶
- Better diffusion through soft and hard tissue.²⁷

The conclusion drawn is that Articaine is a safe and effective local anaesthetic for use in clinical dentistry,²⁵ however, there are no significant benefits of using Articaine (4%) compared with Lidocaine (2%) for IDBs.^{23,28}

There is, however, some concern with regard to using Articaine for inferior alveolar and lingual nerve blocks.^{16,29,30} This persistent altered sensation may be due to the high concentration of the local anaesthetic; however, the technique cannot be excluded as the cause for nerve injury.¹⁶ Another report suggests that it is the type of anaesthetic that dictates the degree of inflammatory reaction to local anaesthetic, Lidocaine being the least irritant followed by Articaine, Mepivacaine and Bupivacaine.³¹ The components of Septocaine only differ in the active local analgesic content and concentration and it is not yet conclusive whether this agent is more likely to induce permanent nerve injury.

Persistence of any peripheral sensory nerve injury depends on the severity of the injury, increased age of the patient, the time elapsed since the injury and the proximity of the injury to the cell body (the more proximal lesions have a worse prognosis). Many authors recommend referral of injuries before 4 months,¹³ but this may be too late for many peripheral sensory nerve injuries. We now understand that, after 3 months, permanent, central and peripheral changes occur within the nervous system subsequent to injury that are unlikely to respond to surgical intervention.³

The nerve that is usually damaged during inferior dental nerve block injections is the lingual nerve, which accounts for 70% of the nerve damage.¹⁵

One suggestion is that this is more likely to be the result of trauma, and that over-reporting of such injuries occur when a new drug formulation, such as 4% Articaine, is introduced. There is another explanation why the lingual nerve is more likely to suffer damage. This relates to its structure. At the region of the mandibular lingula, the lingual nerve is composed of very few fascicles and, in some individuals, it is unifascicular at this point,¹⁵ unlike the inferior alveolar nerve, which is multifascicular in this region. This structural difference may explain why the lingual nerve is more susceptible than the inferior dental nerve to injection damage.

Interestingly, more recently, Articaine infiltrations are demonstrating similar efficacy to Lidocaine IDBs for mandibular dentistry, therefore obviating the necessity of an IDB altogether.^{32,33} It has become routine practice for paedodontic extraction of premolars using Articaine infiltrations and many practitioners are routinely undertaking restorative treatment of premolars and molars in adults using LA infiltrations rather than inferior alveolar nerve blocks. This would reduce the incidence of these troublesome untreatable injuries.

Therefore, prevention of LA nerve injuries is possible and some simple steps may minimize LA-related nerve injuries:

- Avoid high concentration LA for IDBs (use 2% Lidocaine as standard);
- Avoid multiple blocks where possible;
- Avoid IAN blocks by using high concentration agents (Articaine) infiltrations only.

Intra-operatively, all clinicians should document unusual patient reactions occurring during application of local analgesic blocks (such as sharp pain or an electrical shock-like sensation).

Implant-related nerve injuries

The incidence of implant-related inferior alveolar nerve (IAN) nerve injuries vary from 0–40%.^{13,18,34–39} Of edentulous patients, 25% present with a degree of altered IAN function, thus reinforcing the guidelines on the necessity of pre-operative neurosensory evaluation.

Great care must be taken when selecting the patient and possible sites for implant placement.⁴⁰ Appropriate radiographic evaluation of the implant site is indicated. Harris *et al*⁴¹ have reported

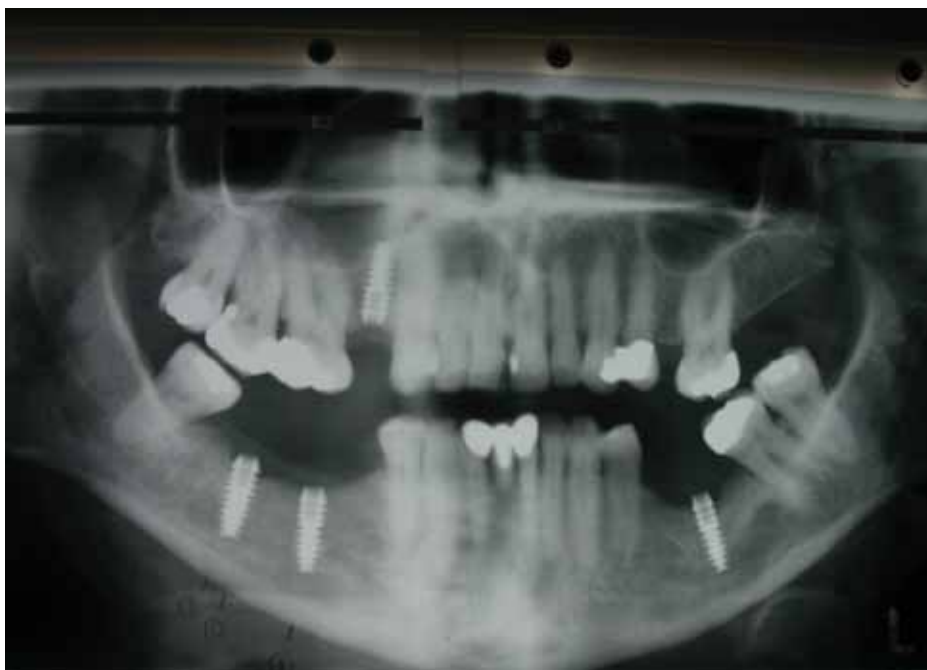


Figure 1. A dental panoromograph illustrating a case with bilateral IAN injury resulting from inadequate safety zone provision.

explicit recommendations for pre-operative radiographic evaluation prior to placement of implants. Cone beam CT scanning, now introduced to many specialist practices and dental hospitals, will provide low radiation dosage and improved imaging for planning implant treatment. Several papers have drawn attention to the weakness of CT evaluation in identifying the IAN canal, with poorer sensitivity and specificity compared with pantomogram radiography.⁴² In 15% of patients, the mandibular canal was not adequately visualized, and a computed tomography (CT) scan was used to plan the implant locations.³⁷ Many practitioners use software to assist in the planning of implants and for the identification of the IAN canal position, with the specific aim to place the implants with a safety zone of more than 2 mm from the IAN canal.⁴³ It may be prudent to highlight that it is the practitioner that draws in the IAN canal for assessment, which will not be objective but merely subjective and increasingly leads practitioners in the USA to recommend a safety zone of a minimum of 4 mm. More recently, Abarca *et al*⁵ have highlighted the necessity for cross-sectional imaging, even for surgical procedures in the symphyseal region owing to unforeseen nerve injuries. Most cases of iatrogenic paraesthesia can be prevented but not remedied. However, when this problem occurs, follow-up must be initiated quickly, since the first few months may determine the degree of nerve healing.

With the specific aim to place the implants with a safety zone of more than 2 mm in order to prevent nerve injury (Figure 1), many practitioners in the USA are recommending a minimum safety zone of 4 mm.⁴³ Once a safety zone is identified, implants can be placed anterior to, posterior to, or above the mental foramen; and, prior to placing an implant anterior to the mental foramen that is deeper than the safety zone, the foramen must be scrutinized to exclude the possibility that an anterior loop is present. Clinicians must have an awareness that certain prep drills are up to 1.5 mm longer than the placed implant. In general, altered lip sensations are preventable if the nerve and mental foramen are located, and this knowledge is employed when performing surgical procedures in the foraminal area.⁴³

Implant burs vary, depending on

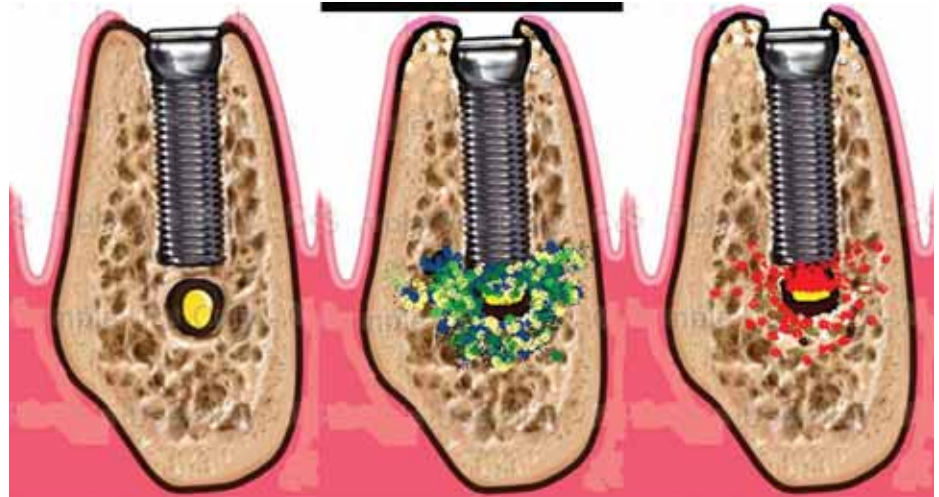


Figure 2. Possible aetiology of nerve injury. The nerve injury may be due to direct mechanical trauma by the preparation bur or implant (a), extrusion of debris into the canal (b), but is most likely due to haemorrhage caused by preparation which continues after implant placement and results in nerve ischaemia (c).

the manufacturer, and must be understood by the surgeon because the specified length (for example, a 10-mm marking) may not reflect an additional millimetre (or up to 1.5 mm) included for drilling efficiency. When placing implants in proximity to the mental foramen, the clinician must take into consideration the anterior loop of the nerve,³⁸ as well as the available bone above the mental foramen, because the inferior alveolar nerve often rises as it approaches the mental foramen (compared with its height in the molar region). Implant bed preparation is the most probable cause of the IAN injuries in the patient cohort that the author has evaluated, thus explaining the often 'distant' implant from the IAN canal with nerve injury but subsequent osseointegration and bony infill.

A sudden 'give' during preparation may be indicative of protrusion through the lingual or buccal plate but may also be associated with fracturing of the IAN canal roof, which will increase the risk of haemorrhage into the canal and subsequent compression of the nerve. It will furthermore increase the likelihood of extrusion of preparation debris or alkaline solutions being introduced into the canal, also causing potential harm to the nerve. If there is an inferior alveolar arterial or venous bleed, it may be advisable not to place the implant and to wait 2–3 days to ensure no nerve damage has occurred and then place the implant in granulation

tissue, which should not compromise the success of the implant. However, there is no evidence to support this practice yet. If a nerve injury is suspected, the clinician should perform a basic neurosensory examination of the neuropathic area and ascertain whether the patient experiences pain, altered sensation or numbness and document the results within the day of surgery (when the effects of the anaesthetic should have worn off). A simple phone call 6 hours post surgery will enable the surgeon to ascertain from the patient whether the analgesic effects of the local analgesia have worn off and if neuropathy is present.

Nazarian *et al*⁴⁴ noted several modalities of implant-related nerve injury which may include direct trauma, inflammation and infection as the main causes of postoperative neural disturbances (Figure 2). These injuries most likely occur during preparation rather than placement. They may be directly related to the depth of preparation, implant length or width.⁴⁵ Trauma may be direct (mechanical or chemical) or indirect (haemorrhage or scarring). The use of BiOss (pH 8.4) in close proximity to the nerve bundle should be avoided. Haemorrhage induced by 'cracking' of the IAN canal roof may compress and cause ischaemia of the nerve if the implant is placed with or without back up, short or long implant. Intra-operatively, all clinicians should document unusual patient

reactions occurring during implant bed preparation or placement (such as sharp pain or an electrical shock-like sensation) and IAN vessel bleed.

Post-operatively, the patient should be contacted after the LA has worn off. If IAN injury is evident then consideration should be given to removing the implant within 24 hours of placement (Figure 3). Removal later is unlikely to resolve the nerve injury.

Bone graft harvesting is also associated with IAN injuries.⁴⁶ Again it is crucial that appropriate training, planning and assessment should be undertaken in order to minimize nerve injury.⁴⁷ Avoidance of implant nerve injury is sometimes attempted by using techniques including inferior alveolar nerve lateralization and posterior alveolar distraction, however, these high-risk procedures are more likely to result in inferior alveolar nerve defect, regardless of the surgeon's experience.

Prevention of implant nerve injury

The most significant issue with implant-related nerve injuries are that they are avoidable, potentially permanent, with or without surgical intervention.¹⁵

Intra-operatively

- Do NOT place implant with intra-operative bleed, place implant 2–3 days later.

Post-operatively

- Routinely check on patient early post-operatively at 6 hours.
- If patient has neuropathy immediately after local analgesia has worn off:
 - consider removing the implant in less than 24 hours.
- Steroids and NSAIDS.
- Refer to specialist.

Home check

Routinely contact patients post-operatively to ensure local analgesia has worn off. If nerve injury occurs or is suspected after the procedure, the clinician must inform the



Figure 3. Illustrating implant bed after removal of implant from LL5 region within 24 hours, with successful resolution of IAN injury within 3 days.

patient of its existence immediately and make a timely referral to an appropriately trained microneurosurgeon if necessary.

Non placement of the implant

If an implant is potentially violating the canal, with a sudden 'give' experienced during preparation, its depth could be decreased in bone (by unscrewing it a few turns 'back up' which may leave excessive implant exposed coronally) and left short of the canal or replaced with a shorter implant. However, if a bleed is identified, the implant should be removed immediately.¹³ The author recommends removing the implant immediately and replacing it several days later when initial healing has taken place, allowing optimal neural healing.

Late removal of implant

It is evident from the patient cohort evaluated that nerve injury appears to be permanent, even at weeks post injury and even with the case where the implant was removed within 24 hours.⁴⁷ If neural recovery is to be optimized, the potential harmful implant must be removed very early on when there is persistent neuropathy after the LA has worn off (4–6 hours). However, this may still be too late. With patients presenting with IAN neuropathy late post-operatively, the author no longer removes the implant, along

with other specialists (Pogrel A, personal communication), as it appears to be of little value in reversing nerve damage and associated symptoms.

Therefore, these injuries may be irreversible and place the emphasis on prevention rather than cure:

- Planning >4 mm safety zone;
- Bleed during implant bed preparation and delay implant placement;
- Persistent numbness after LA has worn off – remove implant < 36 hours.

Endodontic nerve injury

Any tooth requiring endodontic therapy that is in close proximity to the IAN canal should require special attention. If the canal is over prepared and the apex opened, chemical nerve injuries from irrigation of canal medicaments is possible, as well as physical injury precipitated by overfilling using pressurized thermal filling techniques.^{48,49} Post-operative RCT views must be arranged on the day of completion, and identification of any RCT product in the IAN canal should be reviewed carefully (Figure 4). If IAN function is compromised after LA has worn off then immediate arrangements should be made to remove the over fill.

The optimum pH of an endodontic medicament should be as close as possible to that of body fluids, ie around 7.35, as higher and lower pHs are likely to

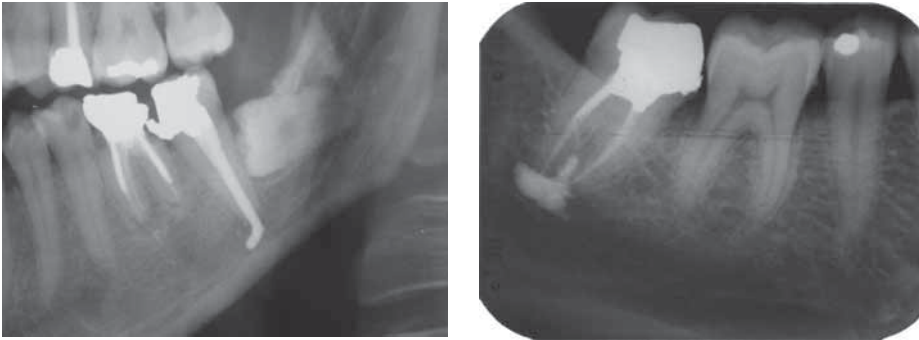


Figure 4. Radiographs illustrating overfill of endodontic material into the IAN canal.

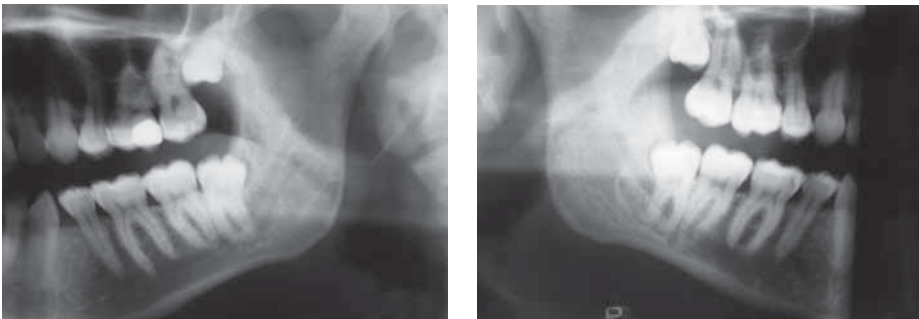


Figure 5. DPT radiographs illustrating two cases of 'high risk' mandibular third molars.

cause cellular necrosis of tissues in direct contact with the medicament. The clinician must also consider the pH of some of the routinely used endodontic and related dental materials:

Commonly used endodontic medicaments

- Formocresol
pH 12.45 +/- 0.02
- Sodium hypochlorite
pH 11–12
- Calcium hydroxide (Calyxl)
pH 10–14
- Antibiotic-corticosteroid paste (Ledermix)
pH 8.13 +/- 0.01
- Neutral
pH 7.35-7.45
- Eugenol
pH 4.34 +/- 0.05
- Iodoform paste
pH 2.90 +/- 0.02

These chemical nerve injuries are commonly permanent and often cause severe neuropathic pain. If the patient is suffering from neuropathy after the LA has worn off, and the post-operative radiographs confirm the diagnosis, ie gutta percha, or some other root canal filler extrusion into the IAN canal, management

should be by immediate removal of endodontic materials via tooth apicectomy or tooth extraction (may require a specialist endodontist).

If endodontic nerve injury is suspected, the post-operative radiograph must be scrutinized for evidence of breach of the apex and deposition of endodontic material into the IAN canal. If this is suspected, the material, apex and/or tooth must be removed within 24 hours of placement in order to maximize recovery from nerve injury.

Third molar surgery-related nerve injury

Third molar surgery-related inferior alveolar nerve injury is reported to occur in up to 3.6 % of cases permanently and 8% of cases temporarily.^{50,51} Factors associated with IAN injury include:

- Age;
- Difficulty of surgery; and
- Proximity to the IAN canal.

If the tooth is closely associated with the IAN canal radiographically (eg superimposed on the IAN canal, darkening of roots, loss of lamina dura of canal, deviation of canal [Figure 5]),⁵⁰⁻⁵⁴ 20% of

patients having these teeth removed are at risk of developing temporary IAN nerve injury and 1–4% are at risk of permanent injury.⁵⁰⁻⁵⁵

Radiographic signs indicative of possible IAN risk include:

- Diversion of the canal;
- Darkening of the root;
- Interruption of the canal LD;
- Juxta apical area.

If these plain film radiographic risk factors are identified, removal of the third molar will result in an elevated risk of IAN injury (2% permanent and 20% temporary). The patient must be informed about this elevated risk.

There is increasing evidence that Cone Beam CT (CBCT) scanning of high risk teeth will further establish the relationship between the IAN and the roots. In many cases the CBCT re-affirms the proximal relationship which would support planned coronectomy if appropriate (but would not change the planned treatment). However, in a few incidences, despite high risk identification based on plain films, some IANs are found to be distant from the roots using CBCT, which would allow for removal of the tooth rather than planned coronectomy.⁵⁶ Further research is required to ascertain the risk benefits of CBCT and whether it is indicated for treatment planning in these high risk cases.

Tantanapornkul *et al*⁴² assessed 161 teeth and reported that the relative sensitivity of CBCT and panoramic assessment was 93% and 70% and the specificity CBCT and panoramic assessment was 77% and 63%, respectively. Jhamb *et al*⁵⁷ compared spiral CT with panoramic assessment and found no significant differences in 31 teeth. Most third molar roots in close proximity to the IAN canal were buccal (45%), in line with the canal (39%), lingual (10%) and 6.4% were inter-radicular; 20% of roots were more than 6 mm from nerve, 3% 0–1 mm, 48% 0 mm with cortication, and 29% 0 mm with cortical break. Friedland *et al*⁵⁸ highlighted the benefits of CBCT imaging for the assessment of high risk third molars. Based on the author's experience, using CBCT may not have a routine role in pre-operative assessment for the removal of third molars in a unit that regularly undertakes coronectomy procedures. Rarely, the tooth is distant (Figure 6) from the IAN canal,

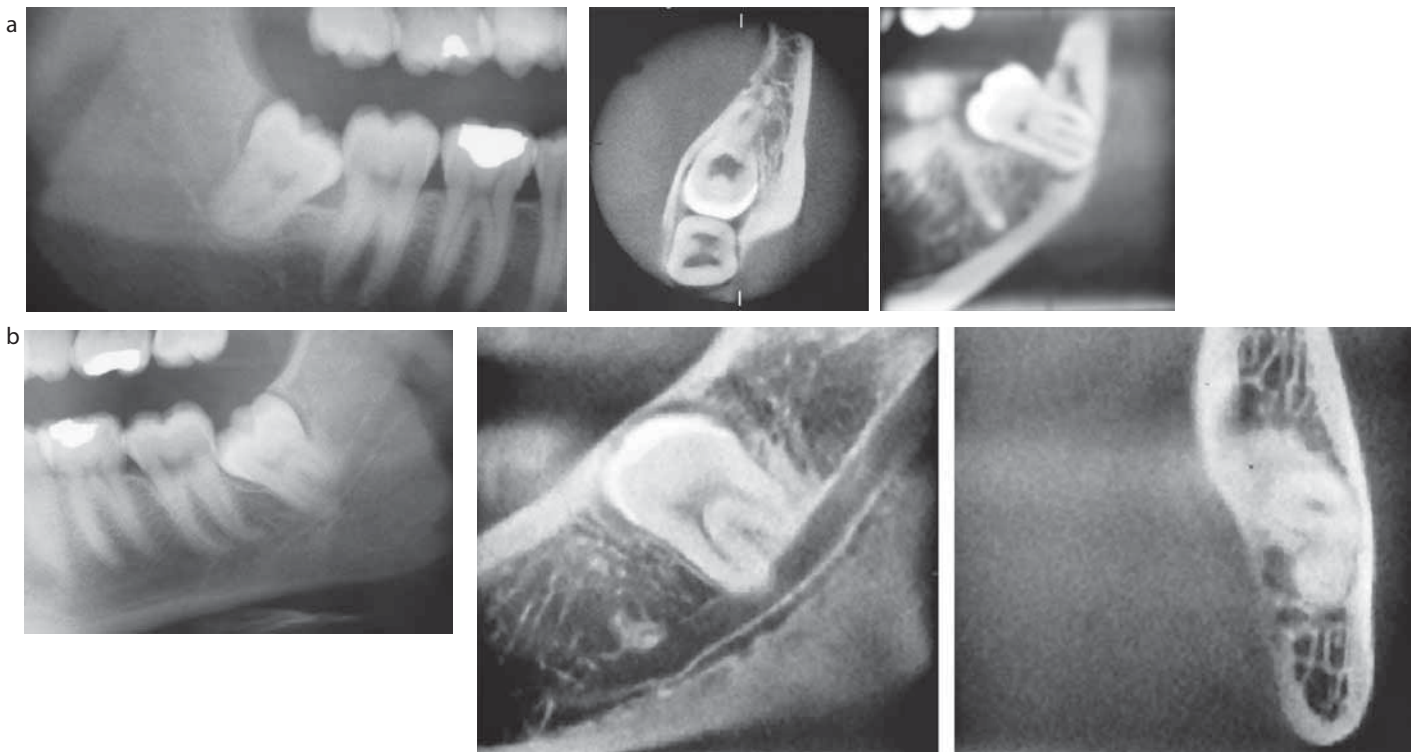


Figure 6. (a) CBCT localizing IAN proximal to lower teeth (distant from nerve). **(b)** CBCT localizing IAN proximal to lower teeth (proximal to nerve).

based on high risk plane film assessment, and would result in a rare change on planned procedure. However, if the patient is compromised or the tooth is non vital and has to be removed, then CBCT may play a role in assisting the surgeon to plan the tooth section in order to minimize damage to the IAN.

Coronectomy avoids the nerve injury by ensuring retention of the roots when they are close to the canal (as estimated on radiographs). The tooth must be high risk, vital and the patient must not be immunocompromised and at higher risk of infection. A study of 100 patients showed that the risk of subsequent infection was minimal and morbidity was less than after the traditional operation.⁵⁵ Over a period of 2 years, some apices migrated and were removed uneventfully under local anaesthetic. Dry socket incidence was similar to the surgical removal group and treated in the same way (using *Corsodyl* irrigation and *Alvogyl* paste). On the premise that coronectomy reduces the risk of nerve injury, it has been recommended for those patients for whom there may be serious repercussions from numbness of

the lip (wind instrument players, actors, singers, and others) and those at higher risk of IAN injury. Renton *et al*⁵⁵ reported that the inferior alveolar nerve was often injured by extraction of third molars, the roots of which were superimposed radiographically on the nerve canal, similar to previous studies.⁵⁰⁻⁵⁵ Most of these injuries were temporary but two were permanent, both of which were treated by tooth removal not coronectomy. We found evidence that some radiographic signs may be more predictive of nerve injury than others, including deviation of the canal at the apex and the presence of the juxta apical area (Figure 7).

Five coronectomy articles report more than a single patient. There are four case series evaluating the coronectomy procedure (50 cases,⁵⁹ 95 cases with 52 patients followed up,⁶⁰ 35 cases⁶¹ and 33 cases⁶²) and the fifth article was a randomized controlled trial.⁵⁵ In all cases, coronectomy was suggested as a technique of partial root removal when *Panorex* imaging suggested an intimate relationship between the roots of the vital lower third molar and the IAN nerve, and the tooth still needed to be removed. (Note: Cone beam



Figure 7. Juxta apical area. This new radiographic sign is a well circumscribed radiolucent area lateral to the root rather than at the apex. MRI and CT studies have elicited that this is likely to be continuity of IAN lamella with the periodontal lamina dura of the adjacent tooth.

CT was not available at the time the studies were conducted.) All papers suggested that the technique had merit and many practitioners regularly use the coronectomy approach in order to minimize IAN injuries.

Coronectomy technique involves using the buccal approach (Figure 8) with removal of the buccal bone using a fissure bur down to the amelo-dentinal junction (crown root junction). The crown is part sectioned from the root using a fissure



Figure 8. Coronectomy technique.

bur and elevated, in a similar way to the buccal approach technique. On elevation of the crown from the roots, mobilization of the roots may occur, particularly if the patient is young, female and the roots are conical.⁵⁵ If the roots are mobilized, they must be removed. Thus the patient must be consented for coronectomy and/or removal if the roots are mobilized intra-operatively. On exposure of the pulp and immobilized roots the surgeon must ensure that there is no enamel retained and the use of a rose head bur may be necessary to remove any enamel spurs. Do not touch or medicate the vital pulp. Closure of the buccal flap over the roots is achieved with 1–2 4/0 vicryl sutures. No antibiotics are recommended, just pre- and post-operative *Corsodyl* and good oral hygiene. The patient must be warned of possible 'dry socket' and to seek treatment if there is persistent pain or swelling.

Reports of complications subsequent to coronectomy are rare. We have had to remove roots in 2 patients of the original 52 study coronectomies at up to 6 years post-operatively.⁵⁵ The patient must be warned of a possible second surgical intervention if complications arise. Four (8%) of our study patients, reviewed

at 2 years post-operatively, showed radiographic evidence of migration of the retained root away from the canal, which may infer that, if the roots do require removal at a later stage, then the risk of damage to the IAN will remain reduced. In our clinics we do not re-treat 'dry sockets' or persistent infection associated with retained coronectomized roots, but prefer to remove the roots early on. This is owing to 2 cases of temporary infection IAN neuritis (<6 weeks post-operatively) associated with infected coronectomized roots. There is a need for reports on long-term evaluation of coronectomy complications.

Prevention of inferior alveolar nerve injuries

During third molar surgery, prevention of inferior alveolar nerve injuries may be possible by:

- A clinical decision based on NICE guidelines that the tooth needs to be extracted (ie do not undertake prophylactic surgery unless indicated);
- Identifying high risk teeth (specific consent) by identifying radiographic risk factors of IAN injury:

- Tooth crossing BOTH lamina

- dura of IAN canal;
- Juxta-apical area;
- Deviation of canal;
- Narrowing of roots.

If the tooth is in close proximity to the IAN on plain film then Cone Beam CT scanning may further elucidate the relationship between IAN and tooth roots. If the tooth is vital and the patient non-compromised, consider coronectomy of the tooth (if the patient is not medically compromised and at increased risk of infection).

If the tooth is non-vital, or pathology associated with it, then tooth removal has to take place and the roots should be sectioned appropriately to minimize trauma to the adjacent IAN and the patient should be warned of the increased risk (2% permanent and 20% temporary) of IAN injury.

Dental extraction of other teeth proximal to the IAN canal

Be aware that any mandibular tooth that is crossing the IAN canal and displays the radiographic signs is associated with an increased risk of IAN injury as seen with third molars. Accordingly, the patient must be assessed, consented and treated in a way similar to the treatment of high risk third molar teeth.

Socket medications

With any mandibular tooth in close proximity to the IAN canal, its extraction can subsequently effectively expose the IAN to socket medicaments. If these are irritant to the neural tissue, they can lead to chemical neuritis and, if persistent, neuropathy, which is untreatable and often associated with neuropathic pain.

There is limited availability of the relative alkalinity or acidity of various dental compounds used for socket medication including; *Alvogyl*, *Whiteheads* varnish, *Corsodyl* and *Surgicel*. However, a previous study highlighted the relative neurotoxicity of *Carnoys* solution, *Surgicel*, *Whiteheads* varnish and *Bismuth Iodoform Paraffin Paste* (BIPP), reporting that *Carnoys* is likely to cause permanent nerve damage and *Surgicel*, along with *Whiteheads* varnish, cause temporary sensory disturbances. BIPP was found to be the least neurotoxic.²¹ Bone

wax has a neutral pH, however, excessive packing or pressure can lead to nerve compression and injury

Post-operative infection

Inferior alveolar neuritis can present as a symptom of local mandibular infection associated with a periapical abscess on a non-vital tooth close to the IAN canal or as a sign of osteomyelitis. This may present as persistent or recurrent dry socket that has required repeated socket irrigation and redressing. Suspicion should arise after the second or third dressing when accompanied by persistent pain and non-response to antibiotics. More recently, with the advent of bone graft surgery for implants, some patient progress on to osteomyelitis associated with non-vital bone grafts that are not removed quickly enough.

Periapical infection

Once IAN neuropathy develops, this may be a sign of spreading bone infection, and the tooth should be removed or endodontically treated to ensure that no bone sequelae or tooth fragments remain.

Possible management protocols used by specialists

The management will depend upon the mechanism and the duration of the nerve injury. Many injuries have limited benefit from surgical intervention and should be managed symptomatically using medication or counselling. Immediate intervention is required for endodontic, implant and third molar-related nerve injuries and immediate referral is suggested for all cases.

Counselling and therapeutic management

Counselling and therapeutic management is indicated for injuries caused by:

- Endo >48 hours;
- Implant >48 hours;
- Wisdom teeth >6months;
- LA;
- Orthognathic treatment;
- Fracture.

Medical symptomatic therapy (pain or discomfort)

- Topical agents for pain;
- Systemic agents for pain.

Surgical exploration

- Immediate repair if nerve section is known;
- Remove implant or endo material within 24 hours;
- Explore IAN injuries through socket less than 4 weeks;
- Explore LN injuries before 12 weeks.

Can we prevent these injuries?

This article highlights some of the potential pitfalls in causing nerve injury and potential strategies on how to prevent them. Prevention is better than cure as once permanent (>3months) nerve injury has occurred the patient is unlikely to regain normal sensation again, despite various interventions.⁶³ The most desirable outcome after nerve injury is spontaneous return of normal sensation. The likelihood of this occurring depends on both the severity of the injury, patient age and the nerve involved. As this article has highlighted, the outcome of nerve injury will depend on multiple factors such as duration and mechanism of injury, appropriate case selection, and treatment planning. When nerve injury occurs, it is imperative that the surgeon recognizes the injury immediately and advises the patient appropriately.⁶⁴ Many injuries can be prevented^{38,45} through better patient selection, planning, and execution of procedures. In addition, patient management can often be improved by informed consent based on risk assessment, and improved post-operative care with early referral for nerve injuries.

Empirically, many patients seen in the author's specialist clinics have significant psychological distress in association with these iatrogenic injuries, particularly when the injury is troublesome or painful neuropathy (which occurs in 70% of patients) and is limiting daily and social function. This is often compounded by a lack of prior informed consent and poor post-operative management by the practitioner subsequent to the nerve injury.⁶⁵

Conclusion

In summary, hopefully, several strategies have been highlighted to assist the practitioner in preventing inferior alveolar nerve injuries, whilst at the same time re-affirming that there is no 'magic bullet' in treating these unfortunate patients.

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