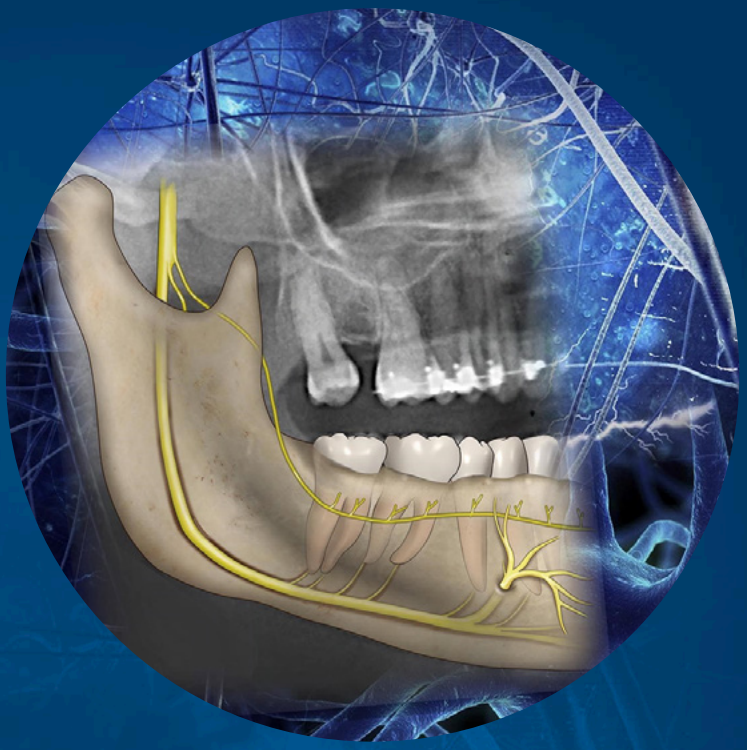
Endodontics and Neurovascular Injury



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ENDODONTICS:

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Introduction:

When planning endodontic treatment on mandibular teeth, the location of the inferior alveolar nerve (IAN) must be taken into consideration. Failure to properly assess the potential for injury to the IAN may result in sensory disturbances such as paresthesia, anesthesia, or dysesthesia to the chin, lip, or associated anatomic structures and dermatomes. (1,2) These post-traumatic sensory neuropathies can present as a range of symptoms from merely a minor annoyance to devastating life-altering changes which can affect everyday well-being. (3) This is why it is critical for the clinician to carefully assess and manage any pending endodontic treatment in the mandible, particularly when a reasonably careful clinician should have foreseen and thus prevented any undue risk of harm to their patient.

Terminologies:

The mandibular branch of the trigeminal nerve exits the skull from the ovate foramen and extends into the infratemporal fossa. Running lateral to the lingual nerve, it becomes the inferior alveolar nerve (IAN). The IAN enters the mandibular foramen on the medial surface of the ramus of the mandible (just below the lingula) and travels through the mandible to the mental foramen which is located on the buccal aspect of the mandible, typically in the area of the first and second premolars. (4, 5, 6) Often there can be multiple mental foramina in this area. (7, 8, 9) After exiting the mental foramen, the IAN becomes the mental nerve to provide sensory innervation to the mentalis area of the mandible, specifically to the area of the soft tissues of the lip and chin. The IAN is encased within the inferior alveolar nerve canal (IANC), which is oriented in the lower half of the mandible, initially more towards the lingual cortical bone of the mandible. Additionally, the IANC can range from being several millimeters from the apices of the teeth to being immediately proximal to the apices. (10,11,12) It tends to be closest to the mandibular second and third molars and is typically more intimately oriented in females. (13,14) Damage to these nerves can result in a myriad of symptoms, most often to the lip and chin, but these injuries can also affect the bone, teeth, and periodontium.

Paresthesia is the sensation often referred to as a "pins and needles" sensation. Often a patient will refer to this as the feeling of a local anesthetic "wearing off." Unfortunately, in the presence of IAN damage, this sensation may persist well after the local anesthetic would have typically dissipated. The area of paresthesia should be assessed by examining with a light pin stick or thermal testing on the skin. It is important to assess and document the location of any paresthesia by drawing the area of altered sensation in the patient record or by marking the affected area on the patient directly and taking a photograph. This documentation is important to record any future increase or decrease of the area of paresthesia.

Anesthesia is a more profound loss of sensation. The patient may report that "the anesthetic never wore off." It is not surprising that a more traumatic injury to the IAN would result in a residual anesthesia as opposed to a paresthesia.

Dysesthesia is the result of an even more severe nerve trauma, resulting in a sharp, lancinating, and often unrelenting pain. Many patients describe a "burning "quality to the pain.

Etiologies:

In dentistry, injury to the inferior alveolar nerve is most commonly caused by third molar extractions, with a local anesthetic injury being the second most common cause. (15) The injury during local anesthetic delivery can be from either needle trauma causing a hematoma and compression within the neural tissues often before the nerve enters the mandible, or chemical toxicity from the local anesthetic agent. This is especially true with higher concentrations (4% solutions) of local anesthetic agents. (16) It has also been shown that mechanical pressure from purulence and edema from a periapical infection can result in paresthesia. However, in this particular situation, when the periapical pathosis resolves, the paresthesia usually resolves concurrently.

In rare instances, non-surgical endodontic treatment can result in paresthesia, anesthesia or even dysesthesia of the inferior alveolar nerve. This can occur because of two possible iatrogenic events: over-instrumentation beyond the terminus of the root by entering and causing IAN injury or a perforation of the root wall in close proximity

Figure 1. The highly complex anatomy on this lower molar in conjunction with poor clinical skills has resulted in a perforated canal. The clinician's desire to deliver the calcium hydroxide down to the apices utilizing a needle delivery, has combined to create an extreme and negligent overfill into the IAN that will affect this female patient for the rest of her life.

to the IANC; and/or a chemical injury from obturation material or intracanal medication, specifically endodontic sealers (or cement) or calcium hydroxide. (Figure 1)

Over-instrumentation can occur during root canal cleaning and shaping, especially when there is an inaccurate working length measurement. As such, rotary or hand files may extend beyond the apex of the root and into the inferior alveolar canal thereby causing a laceration or penetration of that portion of the inferior alveolar nerve. The ensuing physical trauma is often accompanied by inflammatory edema, creating further compression of the nerve and a subsequent posttraumatic sensory neuropathy.

An additional risk of neurologic injury occurs when a syringe is used to place sealers or medicaments. Clinicians must avoid placing excessive positive pressure on the syringe during the placement of any formulation of sealer or medicament, and should ensure that the needle is not bound in the canal nor inserted too deeply into the canal of a tooth with a wide-open apex. Slow injection and constant withdrawal of the needle while the material is being injected is critical for a safe and effective delivery. (17, 18, 19)

If a predisposing risk factor for medicament or sealer extrusion into the periradicular tissues is suspected, such as in open apices, adjacent proximity to the neurovascular anatomy, root perforation or resorption, or a potential root fracture, clinicians should proceed with extreme caution, or consider an alternate method of delivery. (20, 21, 22)

Emergency endodontic therapy in dental offices is a common occurrence. General dentists are often the first responders when patients seek help in resolving dental pain and saving their tooth. Many practitioners choose calcium hydroxide as an intracanal medicament when sufficient time for an urgent care procedure is lacking or when the emergency appointment is unscheduled. As such, during these emergency visits, canals are often not enlarged or shaped to the needed requisites for final disinfection and obturation. These small canal sizes can also lead to an intracanal medicament needle binding in the canal. Before the patient can be referred or returns for completion of the root canal treatment, clinicians may be motivated to place the calcium hydroxide in as convenient a manner as possible. This often involves placement of calcium hydroxide using a needle application for expediency.

Critical circumstances leading to overfilling or extrusion of a medicament may result from the utilization of a fluid formulation of calcium hydroxide or liquid sodium hypochlorite; a needle placed within a canal that is either forced apically or unintentionally locked in an insufficiently shaped canal; a lack of clinician diligence in monitoring the pressure placed on the syringe or using unmonitored amounts of the expressed medicament. Inattention and a lack of caution have the potential to result in a severe and life-changing neurologic injury especially in cases where the mandibular tooth and the neurovascular anatomy are intimately and proximally related. Prior to any endodontic treatment being initiated, the clinician should assess the location of the IANC, especially for mandibular second molars where the IANC is in closer proximity to the root's apex. Typically, for mandibular first molars, the IANC is 1-4mm below the apex of the roots. For mandibular second molars the IANC can be less than 1mm from the root apices. (11, 12, 22). Studies have shown that female cohorts tend to have the IANC located closer to the posterior teeth apices. (14) If the clinician is unsure as to the location of the IANC, additional radiographs should be exposed. Specifically, a panorex, or preferably a CBCT which allows for better 3-D visualization, should always be considered. It should also be understood that the mere presence of bone between the IANC and the root apices is not necessarily protective of the IAN. Studies have shown that there may be slightly denser cancellous bone around the IAN in positions surrounding its length, but there is often not a continuous uninterrupted compact layer of bone surrounding the nerve sheath to act as an intact safeguard. In

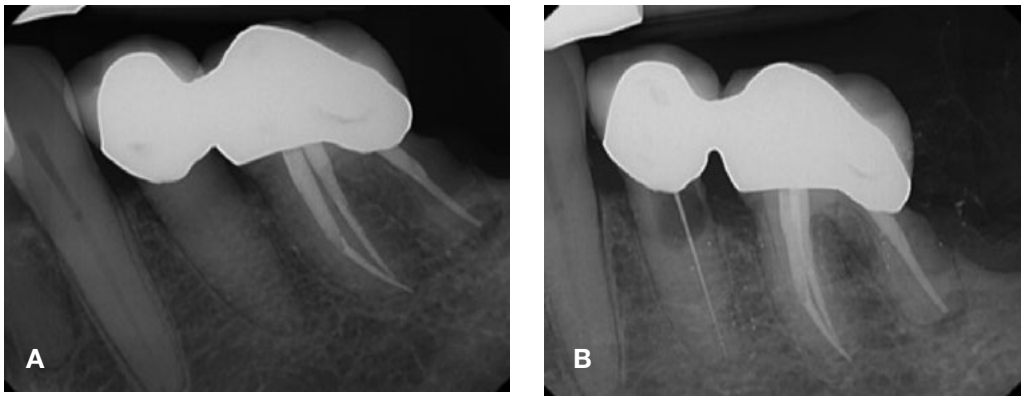


Figure 2A. Tooth number #20. Dentist attempted access on a highly mineralized tooth.

Figure 2B. Access perforated the facial of the tooth below the crestal bone and the dentist believing that the pulp was exposed, irrigated aggressively causing hypochlorite extrusion and neurologic trauma to the mental nerve. Notice the off-centered position of the measurement file.

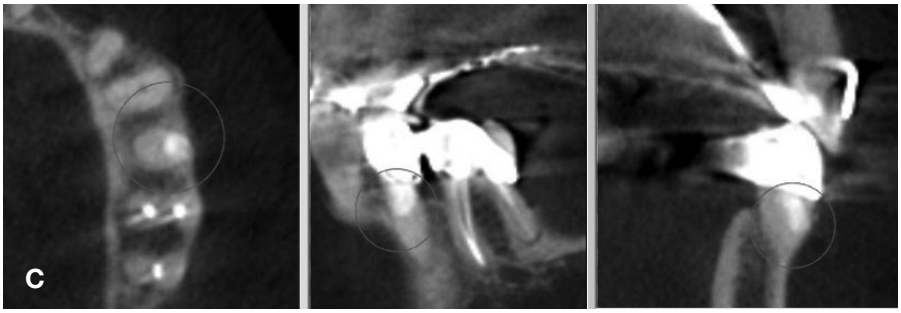


Figure 2C. CBCT imaging demonstrating the perforation and the access orientation.

fact, the surrounding bone typically has multiple areas of perforations which would provide easier access of over-filled sealer or medication into the IANC. (22) Other studies have shown that the mandibular artery rests superior in the IANC. Perforation or laceration of this artery can cause bleeding and edematous pressure on the IAN causing sensory disruption. (10)

The over-instrumentation of the apical foramen or a perforation of the root wall, can have additional untoward sequelae. It can allow easier flow of potentially cytotoxic irrigants (such as sodium hypochlorite) into the periapical tissues and into the IANC, especially if syringe usage and significant positive pressure is applied for delivery of the irrigant. (Figure 2a, b, c) The result can be profound tissue damage and necrosis and a resulting IAN injury. Further, the over-instrumentation of the apical foramen or extrusion through a perforation can create an open passageway for root canal obturation material to enter the periapical tissues and IANC. Whereas an over-extended gutta percha cone (or an obturator) can cause mechanical injury to the IAN as well as local edema-pressure to the nerve (Figure 3), the over-extension of endodontic sealer can cause a chemical burn of the neural tissues and immediate damage. (23) In a recent study of CBCT images, the mandibular canal was seen positioned directly below the molar and second bicuspid roots approximately 50% of the time. (12). The clinician should be aware that root canal sealers typically contain zinc oxide and eugenol, and often calcium hydroxide. In any formulation, calcium hydroxide can be very alkaline. Even the newer bioceramic sealers contain calcium hydroxide in their unset states. All these high pH materials, when in contact with the inferior alveolar nerve, can cause a gradual and persistent insult to the IAN leading to a neuropathy. Left undetected, unmanaged, or ignored by waiting to monitor symptoms, these materials can cause irreversible paresthesia, anesthesia, or dysesthesia, depending on the length of time they are in contact with the neural bundle and the quantities that are over-extended into the IANC.

Figure 3. This IAN overfill was the result of a gutta-percha carrier taken from a heated oven and placed with too much sealer and too much apical force into an apical diameter that was over-instrumented and very large. The resulting overfill was a combination of the operator believing that a gutta percha carrier offered a simple technique and was unaware that the hydraulics of the fill and an over-instrumented apex could result in an extreme overfill, severely injuring this female patient.

Management:

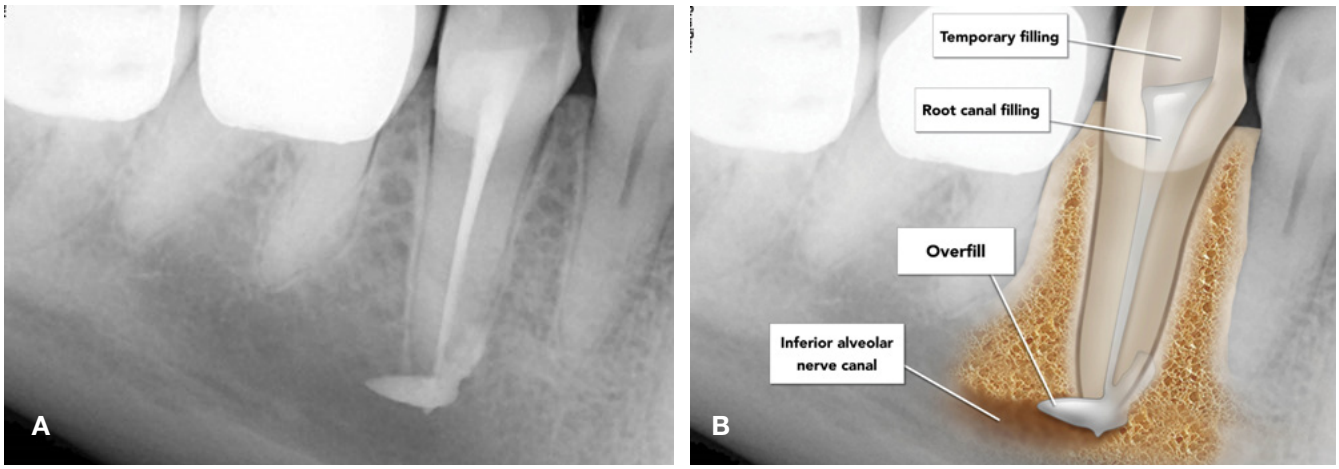
In the event of nerve trauma and hematoma from an anesthetic needle, the resulting paresthesia usually resolves within 8 weeks. Similarly, when paresthesia occurs from purulence pressure on the nerve from a periapical infection, the paresthesia usually resolves once the infection abates from either endodontic treatment or extraction.

Local ischemia from compression of peripheral nerves can result in nerve atrophy in as little as 6 hours. (24) However, when the IAN is traumatized by either an overextended file injuring the nerve, or from the chemical trauma from root canal sealer, the sensory neuropathy can be life-changing to the patient. Studies show that when root canal sealer is permitted to remain in contact with the IAN for more than 24-48 hours, the sensory neuropathy has little likelihood of resolving. (25, 26, 27) Therefore, it is the responsibility of the treating clinician to recognize the ramification of these injuries and to expedite consultation and potential interventional treatment. Early management of these injuries could be extraction of the tooth allowing access to the overfill; or more likely, a buccal corticotomy should be considered in order to gain access and remove the sealer or gutta percha from the area of the IANC. Often these procedures, if timely, can promote repair of the IAN. These techniques have been reported to achieve successful repair of the IAN and return of sensory function in 55% to 92% of cases. (28, 29) If there has not been any sensory improvement after 3 months, with or without interventional surgery, the prognosis for sensory resolution is considered poor.

In considering the literature encompassing this type of injury, the prognosis for altered sensation after extrusion of root filling materials in all cases is ultimately determined by specific tooth locations, types of extruded materials, the obturation technique, and the timing and type of treatment after the injury which can affect the nerve injury prognosis. (30)

Informed Consent:

Many clinicians have an informed consent form for their patients to sign prior to treatment. For endodontic treatment, often there is language that states: "lip or chin numbness may occur following endodontic treatment, which may be temporary or in rare instances may become permanent." Although the clinician (and the patient) may believe this absolves any possible litigation from an IAN injury, this may be a false sense of security. Informed consent, whether in the dental practice or in any aspect of medical treatment, may not apply in the event of negligence. It has been successfully argued in many court cases that the clinician cannot expect the patient to waive their right to competent treatment. As such, the question becomes: "when IAN damage occurs from over-filling into the IANC, can it ever occur without negligence?" When argued effectively by the plaintiff, there have been numerous cases whereby the informed consent has not been permitted to be used as a defense in these legal cases. (Figure 4)



Figures 4A-B. Radiograph demonstrates the intimate relationship of the terminus in this lower bicuspid to the mental foramen. A watch and wait strategy by the practitioner resulted in permanent neurologic deficits to this female patient. The artist's drawing below the radiograph, was used at trial by the plaintiff's legal counsel, to inform the jury regarding the radiographic images.

In summary the clinician should always consider the following when suspecting that root apices are in close proximity to the IAN:

1. Carefully evaluate radiographs/CBCT prior to initiating root canal therapy to identify if teeth are in close proximity to the inferior alveolar nerve, or sinuses.

2. Use care to not over-instrument mandibular premolar and molar apices.

3. Consider the use of a spiral-filler as a safer alternative to syringe needle delivery for sealers or medicaments. Paper points and hand files are additional alternatives.

4. If using syringes, follow the manufacturer guidelines with regards to specific delivery instructions.

5. When injecting medicaments or sealer with a syringe, make sure to properly enlarge the canal so that the needle does not bind in the canal.

6. Use controlled, slow injection and constant outward movement from the canal as the intracanal material is injected.

7. Take appropriate postoperative periapical radiographs to check for material extrusion into the IANC or around the mental foramen or other vital structures.

8. If the patient reports any post-operative symptoms of paresthesia, dysesthesia (burning pain) or numbness within the first 24 -72 hours, document the events and refer to an Oral Surgeon or Endodontist for follow up.

9. In severe cases, surgical intervention might be required in order to debride and remove the overfilled material from the injured neurovascular site.

10. Time is critical in this true neurologic emergency.

Conclusion:

It is well documented that endodontic treatment has a high degree of success. However, the clinician should be aware that morbidities can also occur as a result of endodontic treatment, especially if the clinician is inattentive in the protection of the patient from neurovascular damage and injury. To decrease the incidence of posttraumatic sensory neuropathies, the clinician must be proactive in their assessment of each case, understand pre-operatively the location of the IANC relative to the location of the root apices, and be able to manage any post-treatment complication in a timely manner with an appropriate referral. Radiographs and especially CBCT imaging are essential in assessing the location of the IANC. Obtaining accurate working length measurements is imperative. Additionally, it needs to be appreciated that there is a window of opportunity of approximately 24 to 48 hours to intervene following the recognition of an IAN injury. Failure to adequately make these assessments can have devastating long-term effects for the patient, and your informed consent will not keep you out of a court of law, should negligence be cited.

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‘Only One Drop’

This **Case Feature** provides a meaningful example of the “fine line” between having no patient reaction to an overfill event in a lower molar, and one that can result in litigation. This case involves an endodontist who retreated a missed distal-lingual canal in the lower molar of tooth #18 for a referring general dentist colleague. The case was symptomatic for the patient, and the general dentist had filled the mesial canals only several weeks prior in the case history. Both the general dentist and the endodontist agreed that the distal canal of this molar was the symptomatic culprit. The endodontist knowing the general dentist was competent in clinical endodontics then agreed to only retreat the entire distal canal.

Figure #1 demonstrates the retreatment outcome and if you look carefully, you can see only the very smallest amount of sealer at the distal lingual terminus. Unfortunately, the patient developed a lower left paresthesia with complaints of numbness, some dysesthesia as burning pain and an inability on occasion to control her salivation. The patient was angry and frustrated that her symptoms did not abate within a reasonable timeframe and sought legal counsel against both the general dentist and endodontist.

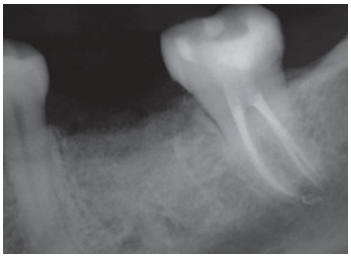

Figure 1. Retreatment of #18, distal canal by endodontist

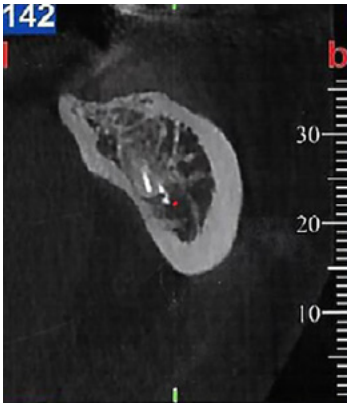

Figure 2. CBCT DICOM image 142 shows a single drop of sealer in proximity of IAN (marked with red dot).

A CBCT was taken during the course of discovery, and it was determined that there was a single slice in the DICOM imaging format that demonstrated a single microscopic “pinhead” of sealer on slice 142 of the scan. This extremely small amount of sealer adjacent to, **but not inside the IANC,** was capable of creating a chemical source of inflammation inside the fascicles of the IAN to interrupt signal transmission for this patient.

Legal counsel and the patient, realizing there was no negligence involved in this patient’s care and treatment, subsequently dropped the lawsuit.

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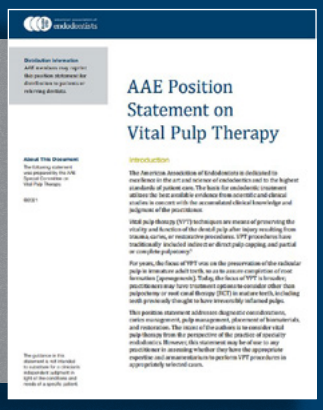

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