CHAPTER 1

Anatomic and Legal Considerations in Dentoalveolar Surgery

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An understanding of the anatomical relationships within the region of dentoalveolar intervention is critical to the avoidance of complications. Radiographic imaging assists in the assessment of anatomical variation and allows for risk stratification and predictable treatment outcomes.

Infratemporal Fossa

The infratemporal fossa is a space located deep to the zygomatic arch and masseteric muscle. The medial boundary of the infratemporal space involves the lateral pterygoid plate. The contents of the infratemporal fossa include the muscles of mastication, blood vessels (pterygoid venous plexus, retromandibular vein, maxillary artery and vein, inferior alveolar artery and vein, middle meningeal artery and vein, deep temporal artery and vein, and buccal artery and vein) and nerves (branches of the maxillary and mandibular nerves, otic ganglion, and chorda tympani).

Due to the complexity of the anatomy and of the contents of the infratemporal fossa, should a maxillary third molar become displaced within the infratemporal fossa (see Figure 1.1), the surgeon should make one to two conservative attempts to remove the displaced tooth only if the tooth can be directly visualized. Blind exploration of the infratemporal fossa is not recommended as it may cause further displacement of the tooth and damage vital structures. Should the attempts be unsuccessful, the procedure should be terminated, imaging in the form of full cranium cone beam computed tomography (CBCT) scans or hospital grade CT scans should be obtained. Three-dimensional imaging will confirm the location of the displaced maxillary wisdom tooth. The patient is informed and the tooth is allowed to fibrous for 3–4 months prior to removal in an OR setting with general anesthesia. A CT scan is obtained a few days prior to the removal of the displaced wisdom tooth in order to confirm its position as the tooth may migrate. If the maxillary third is impacted high within the infratemporal fossa, it is best approached with a horizontal or curved incision within the hairline at the level of the superior temporal line (attachment of the temporalis fascia).

Nasal Cavity

The palatal process of the maxilla contributes to the anterior three-fourths of the nasal floor. The posterior one-fourth of the nasal floor is comprised from the horizontal process of the palatine bone. Care must be taken during placement of anterior maxillary implants to avoid violating this region. Care must be taken when extracting impacted anterior maxillary supernumerary teeth to not displace impacted teeth within a potential space deep to the periosteum along the nasal floor (see Figure 1.2).

Maxillary Sinus

The maxillary sinus is the largest of the paranasal sinuses. It is pyramidal in shape with its apex oriented toward the zygoma. It lies within the posterior maxilla bounded by the infratemporal fossa, lateral nasal wall, and floor of the orbit. As a result of pneumatization, extensive variation exists; however, the average volume in adults is roughly 15 mL. Additionally, the maxillary sinus cavity may occasionally be divided by septae. The maxillary sinus ostium is located along the superior aspect of the medial wall of the sinus and drains into the middle meatus of the nasal cavity.

Third molars may be displaced into the overlying maxillary sinus during their extraction. Should maxillary third molar displacement occur, the location of the third molar must be confirmed (maxillary sinus, soft tissue posterior to the tuberosity or infratemporal fossa). If the wisdom tooth can be visually or radiographically confirmed within the maxillary sinus (see Figure 1.3), one to two attempts should be made through the extraction site to remove the third molar. If this is not possible, a Caldwell Luc approach is indicated. Significant enlargement of the extraction site may lead to the development of an oral-antral communication and should be avoided.

Atlas of Operative Oral and Maxillofacial Surgery, Second Edition. Edited by Christopher J. Haggerty and Robert M. Laughlin.

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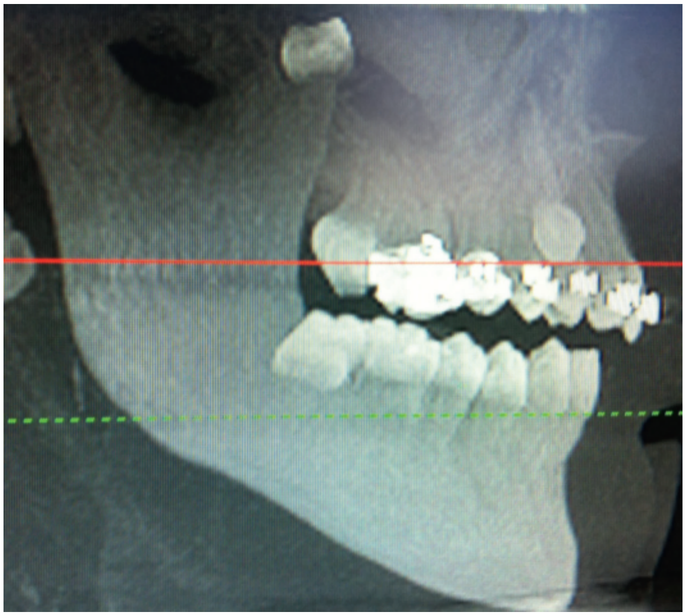

Figure 1.1. Cone beam CT scan depicting maxillary third molar displaced within the infratemporal fossa during a routine wisdom teeth extraction procedure.

Figure 1.2. Coronal CBCT image depicting an impacted inverted mesiodens located along the nasal floor. Care should be taken during the extraction of anterior maxillary supernumerary teeth to not displace the impacted teeth outside of the alveolar process of bone and into the nasal cavity.

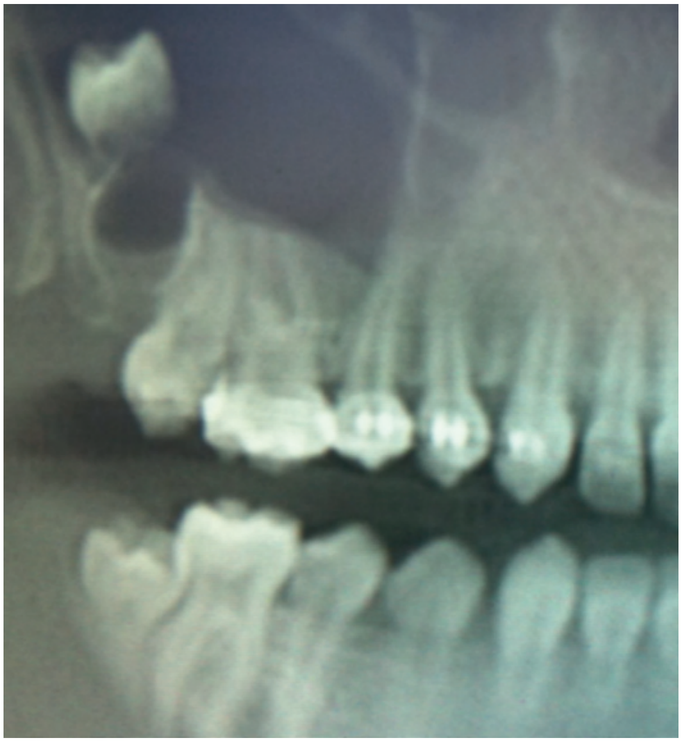

Figure 1.3. Tooth #1 traumatically displaced into the overlying maxillary sinus. The tooth was retrieved through the extraction site using a suction tip.

Mandible

Lingual Nerve

The lingual nerve (LN) provides sensation to the anterior two-thirds of the tongue. The lingual nerve is at risk for injury with the extraction of third molars and with procedures involving the floor of the mouth. Within the third molar region, the lingual nerve is located, on average, 3.0 mm apical to the crest of the alveolar ridge and 2.0 mm medially from the lingual cortical plate. In 17.6% of the population, the lingual nerve is at or above the crest of the alveolar bone. In 22% of the population, the lingual nerve contacts the lingual cortex adjacent to the third molar region. Within the second molar region, the lingual nerve is located, on average, 9.5 mm inferior to the cementoenamel junction (CEJ). Within the first molar and second premolar regions, the average vertical distances from the CEJ lingually are 13.0 and 15.0 mm, respectively. The lingual nerve begins to course toward the tongue between the first and second molar regions. Due to its anatomic location, as well as possible individual patient variations in position, the lingual nerve is at risk for injury during third molar surgery.

Lingual nerve injury can be associated with presurgical pericoronitis, the presence of a presurgical anatomic lingual cortical defect, lingual flap retraction, placement of surgical incisions too far lingually, violation of the lingual cortex with rotary instruments, lingual angulation of the third molar tooth, and surgeon inexperience.

Mental Nerve

The mental foramen typically lies between the first and second premolars in a line corresponding with a vertical reference from the infraorbital foramen. Variability in the vertical distance of the foramen may be problematic in edentulous mandibles with excessive alveolar bone resorption. The mental nerve courses superiorly before exiting the mental foramen. Additionally, the mental nerve commonly loops anteriorly (genu) before its exit from the mental foramen in approximately 48% of the population. The average length of the anterior loop (genu) is 0.89 mm with a range of up to 5.7 mm or more. However, only 5% of individuals have an anterior loop length longer than 3.0 mm and only 2% have an anterior loop length greater than 4.0 mm.

Inferior Alveolar Nerve

As the inferior alveolar nerve (IAN) descends from the base of the skull, it traverses the pterygomandibular space and enters the mandibular foramen approximately 1.5–2.0 cm inferior to the sigmoid notch. Within the corpus of the mandible, the course of the mandibular canal in the buccal-lingual dimension tends to follow one of three general patterns:

- Type 1: in the majority of the population (approximately 70%), the canal follows the lingual plate within the ramus–body region.
- Type 2: in 15% of the population, the canal initially runs within the middle of the ramus when posterior to the second molar, and then follows the lingual plate as it passes through the region of the second and first molars.
- Type 3: in 15% of the population, the canal is positioned in the middle to lingual third of the mandible along its entire course.

In addition:

- In approximately 80% of the population, the inferior alveolar artery courses above the nerve within the bony canal.
- Older patients have been shown to have less distance between the buccal cortex of the mandible and the lateral aspect of the canal.
- In relation to impacted third molars, the inferior alveolar canal is located (see Figure 1.4):

  Lingual to the third molar in 49% of the cases
  Buccal to the third in 17% of the cases
  Inferior to the third molar in 19% of the cases
  Interradicular in 15% of the cases

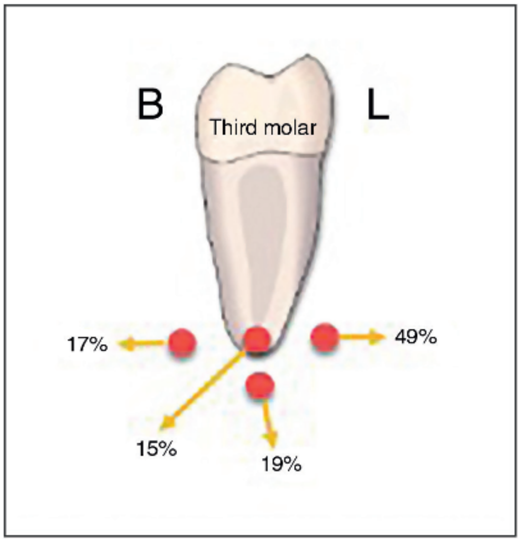

Figure 1.4. Schematic demonstrating the location of the inferior alveolar nerve in relation to an impacted mandibular third molar.

In general, the risk of exposure of the inferior alveolar canal during third molar removal is greater in patients with lingual, rather than buccal, canal positioning. Among molars in the posterior mandible, the distance from the buccal cortex to the canal tends to be greatest within the region of the second molar.

The risk of IAN injury secondary to the extraction of third molars has been correlated with advanced age of the patient (35 years and older), female gender, the use of certain local anesthetics with high concentration, the presence of completely developed roots, the depth and angulation of the impacted third molar, the difficulty of the surgical procedure, the proximity of the tooth in relation to the mandibular canal, surgical sectioning of teeth with exposure of the IAN canal, the use of a surgical bur in close proximity to the mandibular canal, the use of intracanal medications for dry socket prevention, and surgeon inexperience.

Legal Considerations with Nerve Injury (Lingual Nerve and Inferior Alveolar Nerve)

If a nerve injury is not observed at the time of procedure and is reported by the patient at a follow-up appointment, neurosensory testing should be performed to determine the degree of sensory impairment and to establish baseline criteria. Patients should then be followed every 2–4 weeks to monitor recovery. If the injury is a neurapraxia, spontaneous recovery is expected within 2 months, and no surgical intervention is indicated unless MRI demonstrates the presence of a foreign body impeding nerve regeneration.

Indications for microneurosurgery include observed nerve transection, persistent hypoesthesia for 3 months with no improvement, complete anesthesia, pain secondary to neuroma formation, symptoms due to nerve entrapment, progressively worsening hypoesthesia, complaints of dysesthesia, and/or hypoesthesia that is unacceptable to the patient and the presence of a foreign body (root tip, bur, etc.) within the mandibular canal.

Imaging plays a vital role in evaluation of a nerve injury. Various imaging modalities can be utilized post-surgery for the assessment of nerve injury, including panoramic radiograph, CBCT scan, and high-resolution magnetic resonance imaging (MRI), as well as magnetic resonance neurography (MRN).

If microsurgical nerve repair is warranted, surgery should be performed within an appropriate time period to maximize the chance for recovery of sensory function. Despite the fact that there are several guidelines pertaining to the timing of surgical intervention, there is limited scientific evidence to support them. The general consensus is that prolonged delay may negatively affect the success of microsurgical repair.

In general, most spontaneous nerve recovery occurs within 3–9 months following nerve injury, but improvement may continue beyond that time frame. Most studies indicate that microneurosurgery that is performed within 3–9 months, when indicated for non-resolving paresthesia, is more likely to result in functional sensory recovery as opposed to delayed microneurosurgical repair. It has been postulated that when the nerve repair is carried out earlier, it may be easier to anastomose the two nerve stump ends. In addition, ganglion cell death may begin to occur within weeks to months following a non-resolving nerve injury, which may limit the prognosis for successful peripheral microneurosurgical repair. When additional time passes, neuroma formation occcurs at the site of injury requiring more extensive nerve excision and anastomosis repair with a nerve graft, thereby possibly affecting the prognosis for recovery. It has also been determined that within 1 year from injury, a significant component of the distal nerve becomes atrophied via Wallerian degeneration and becomes more surgically challenging to repair.

Below is the recommended time frame for consideration for microsurgical nerve repair for non-resolving paresthesia:

Lingual nerve	1–3 months after injury
Inferior alveolar nerve	3–6 months after injury

Broadly, nerve injuries can be classified as observed/open or unobserved/closed injury. Observed nerve transection and nerve injuries with a foreign body present have the best prognosis if managed promptly. If an immediate microneurosurgical repair is not possible, then it should be performed within 3–4 weeks of injury. The optimal time from injury to surgical repair has been studied and most surgeons who perform microsurgical repair are of the opinion that unobserved injuries of the IAN could likely be followed for a longer period of time compared with lingual nerve injuries due to the presence of the mandibular canal that functions as a conduit to allow for improved nerve regeneration, over the LN which resides in soft tissue and is prone to scar formation.

Oral and Maxillofacial surgeons may consider microsurgical repair of a non-resolving nerve injury by 3 months; however, the current evidence demonstrates that the majority of patients undergo surgery beyond this frame due to delayed referrals, insurance authorization, or evidence of continued improvement of sensation. Additionally, the presence of a lingual nerve deficit beyond 3 months has been correlated with a more severe nerve injury, thereby decreasing chances of its recovery either with or without an attempted nerve repair procedure. For this reason, referring a patient to the surgeon who specializes in microneurosurgery within the first 1–2 months after an unobserved injury with persistent symptoms may be beneficial. Patients who report worsening symptoms of hypoesthesia or dysesthesia should be considered for surgical repair promptly after the degree of injury is assessed and classified by an experienced microneurosurgeon, whereas patients who continue to improve, even slowly, may be monitored.

Regarding lingual nerve injuries, the recovery of taste (via the chorda tympani branch of the facial nerve) following nerve injury and/or nerve repair, may not correlate with recovery of sensation (lingual nerve) in the anterior two-thirds of the tongue.

Key Points

1. Panoramic indicators of IAN proximity include darkening of the third molar root, interruption of the white line of the mandibular canal (see Figure 1.12 in Case Report 1.2), diversion or displacement of the mandibular canal (see Figure 1.9 in Case Report 1.1), abrupt deflection of the third molar roots, and abrupt narrowing of the tooth root.
2. CBCT scanners have aided greatly in the visualization and avoidance of neurovascular structures during dentoalveolar and implant placement surgery.
3. Patient discussions prior to any surgery should involve a detailed review of the consent forms and radiographs. Open ended discussions that thoroughly explain the risks of surgery and documentation of that discussion are necessary. Patients should be offered various treatments and should have an understanding of the advantages and disadvantages of all treatment options. For mandibular third molars in close association to the IAN, patients may be offered a coronectomy as an alternative to complete extraction.
4. All nerve injuries require detailed documentation with neurosensory mapping and completion of a neurosensory testing form, with or without clinical photographs (see Figures 1.7 and 1.8). A clinical

neurosensory testing form should be completed at each patient visit in order to record and compare the areas of involvement over time. The additional documentation aids in determination of the patient's improvement, establishes a diagnosis and reasonable treatment strategy, and if necessary, helps to protect the surgeon against potential legal ramifications. A sample Clinical Neurosensory Testing Form can be found in **Appendix 1** within the Appendix section of the Atlas. www.wiley.com/go/haggerty/oral_maxillofacial_surgery

5. Nerve injuries require early documentation and close follow-up until either spontaneous recovery or until a referral is generated to a nerve specialist. It is crucial to discuss the nerve injury with the patient using universally accepted terminology that the patient can understand and if necessary, the reasoning behind initiating a referral for surgical consultation to an oral and maxillofacial surgeon who is trained in microneurosurgery.
6. Nerve injuries are classified using either the Seddon or Sunderland classification system (Table 1.1).
7. The referral to a nerve specialist in a timely manner is key for injuries that fail to improve over time. In general, the referral should be made within 3 months for lingual nerve injuries and within 6 months for IAN injuries.
8. The decision to monitor versus treat, and how soon to perform microsurgical repair after a nerve injury is contingent upon various factors: (i) observed transection versus closed injury; (ii) patient's present complaints and symptoms; (iii) neurosensory testing and associated findings; (iv) diagnostic imaging; (v) continuous improvement; (vi) risks versus benefits if the repair is warranted. Ultimately, the best protocol is the one that can be tailored to the individual patient's needs.
9. The initial non-surgical management of nerve injuries, specifically neuropraxia, where a witnessed transection has not occurred, may involve agents such as corticosteroids and gabapentin. Steroids should be administered immediately after the clinical diagnosis of nerve injury and will decrease inflammation and edema at the surgical site. The exact dosage and duration of steroid administration is controversial. Gabapentin may be used to manage patients with neuropathic pain and discomfort. Therapeutic agents are not a substitute for definitive surgical repair of nerve injuries that fail to respond over time.
10. Should a maxillary wisdom tooth disappear from the surgical field during its extraction, its location must be confirmed. The maxillary third molar will typically become displaced into the overlying maxillary sinus cavity, into the infratemporal fossa, or within the soft tissue posterior to the maxillary tuberosity. The displacement of maxillary third molars can be minimized by always having direct visualization of the tooth, by being judicious with the amount of pressure applied and of the vector of forces applied, and by placing a retractor along the posterior aspect of the impacted molar site to minimize posterior displacement.

Table 1.1. Seddon and Sunderland classification of nerve injuries.

Injury Classification	Etiology	Healing	Microsurgery
Neurapraxia (Seddon) First-degree injury (Sunderland)	Minor nerve stretch, compression, or traction injury; conduction block	Spontaneous recovery in less than 2 months	Not indicated unless foreign body impeding nerve regeneration
Axonotmesis (Seddon) Second-degree injury (Sunderland)	Crush or traction injury	Spontaneous recovery in 2–4 months, Up to 1 year for complete recovery	Not indicated unless foreign body present
Third-degree injury (Sunderland)	Traction, compression, or crush injury	Some spontaneous recovery, but not complete	Microsurgery indicated if no improvement by 3 months
Fourth-degree injury (Sunderland)	Traction, compression, injection, or chemical injury	Poor prognosis for spontaneous recovery, High probability for neuroma formation or intraneural fibrosis	Microsurgery indicated if no significant improvement after 3 months
Neurotmesis (Seddon) Fifth-degree injury (Sunderland)	Transection, avulsion, or laceration of nerve trunk	Poor prognosis, Extensive fibrosis, neuroma formation, or neuropathic changes	Microsurgery indicated if no improvement after 3 months or development of neuropathic response

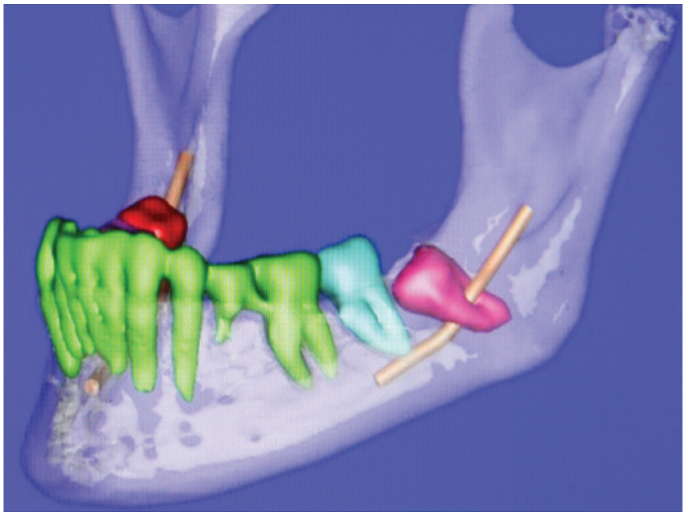

Figure 1.5. Three-dimensional image depicting the inferior alveolar nerve coursing directly through an impacted lower wisdom tooth.

Figure 1.6. Lower wisdom tooth extracted from the patient in Figure 1.5. The yellow paper represents the location of the inferior alveolar nerve through the apical portion of the wisdom tooth.

Figure 1.7. Photographic documentation of a lingual nerve (LN) injury.

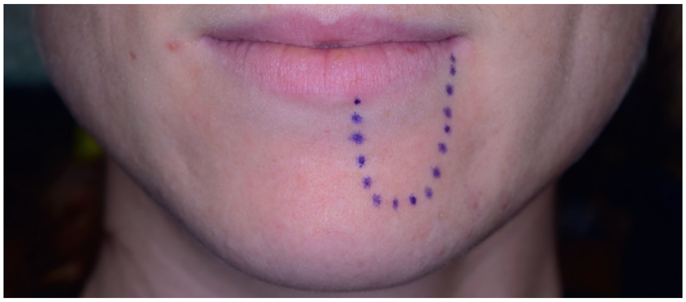

Figure 1.8. Photographic documentation of an inferior alveolar nerve (IAN) injury.

Case Reports

Case Report 1.1. Coronectomy. A 63-year-old patient presents with a chief complaint of pain, foul taste, persistent food impaction, and chronic localized infection to site #32. Based on the patient's age, nerve anatomy, and potential for permanent neurosensory damage, the decision was made to remove the coronal aspect (clinical crown) of the impacted tooth without extracting the root tips (i.e., **coronectomy**) (see Figures 1.9 through 1.11).

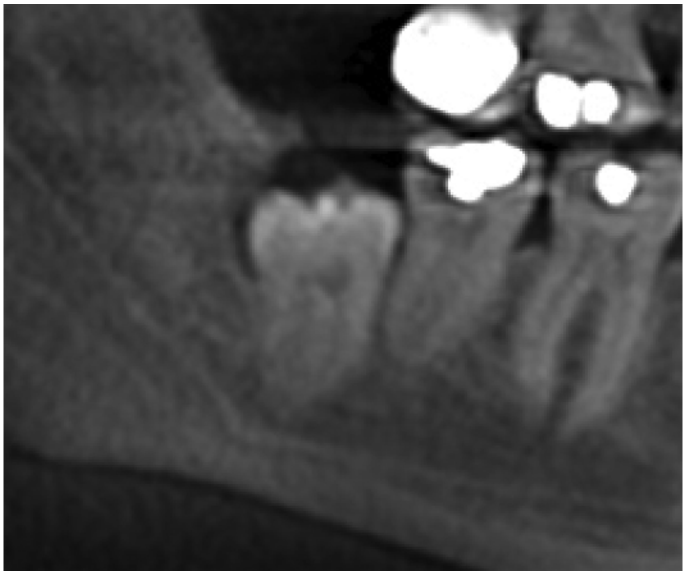

Figure 1.9. Two-dimensional film demonstrates impacted tooth #32 with diversion of the mandibular canal at the apex of the tooth.

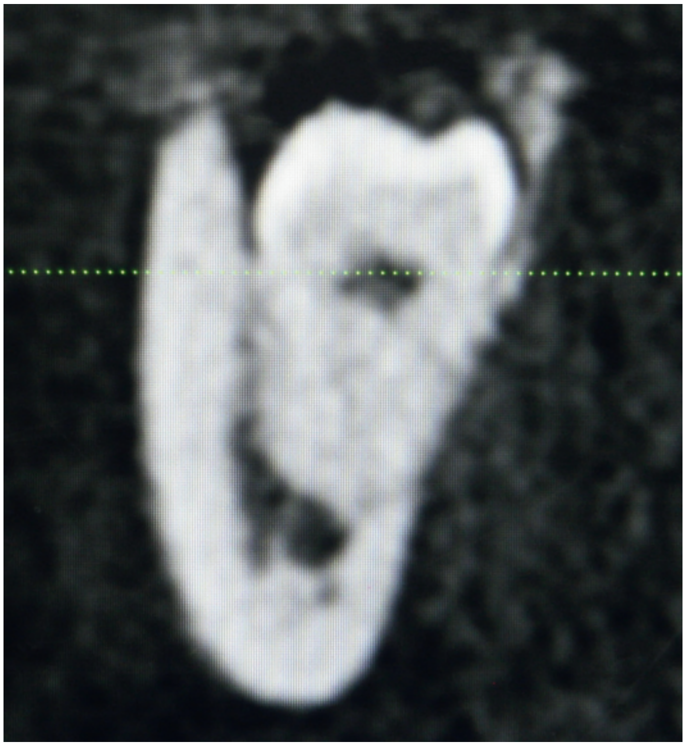

Figure 1.10. Cone beam computed tomography coronal view demonstrating the inferior alveolar nerve coursing through the apical third of tooth #32.

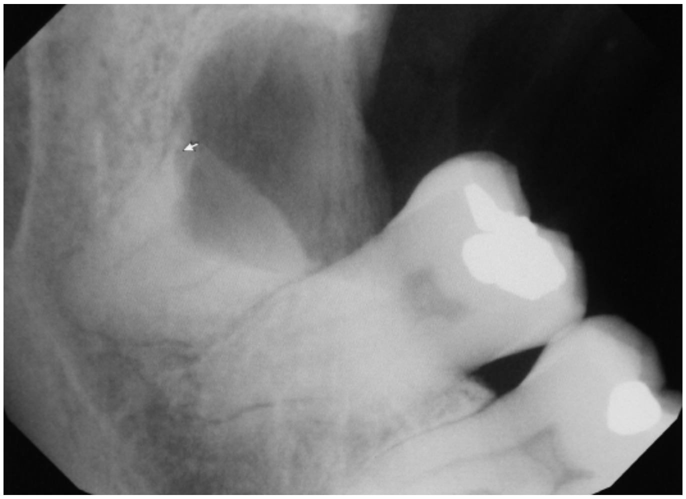

Figure 1.11. Periapical film demonstrating a coronectomy of tooth #32. Note that the entire clinical crown was removed by sectioning the tooth apical to the CEJ. The retained root structure was further reduced 3–4 mm below the bony margin to ensure that no residual enamel remained.

Case Report 1.2. A 57-year-old patient presents with a chief complaint of persistent local pain, referred pain, and documented deep probing depths to site #32 (see Figures 1.12 through 1.14).

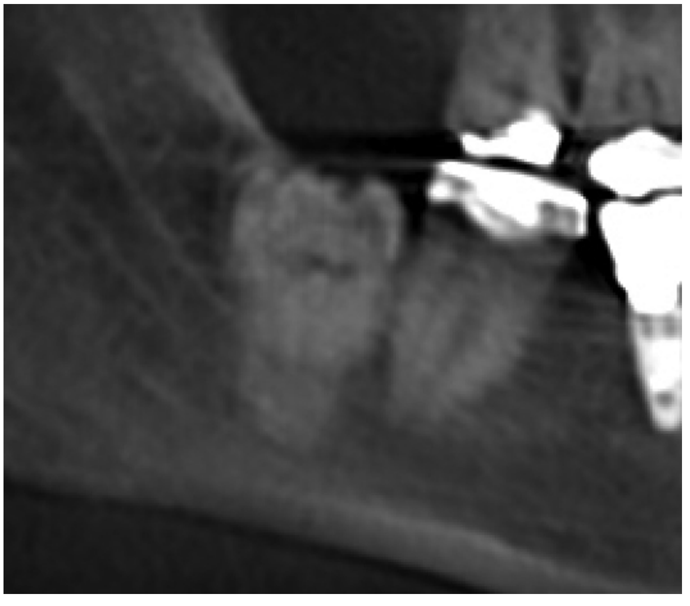

Figure 1.12. Two-dimensional film demonstrating interruption of the white lines of the mandibular canal at the apex of impacted tooth #32.

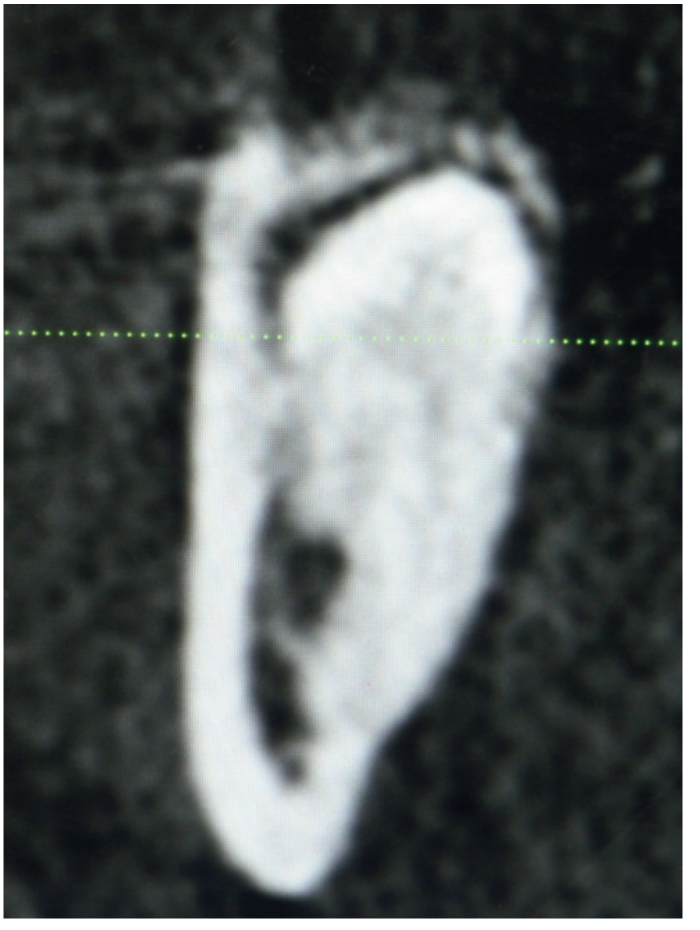

Figure 1.13. Cone beam computed tomography coronal view demonstrating the inferior alveolar nerve coursing through the middle third of the third molar root.

Figure 1.14. Tooth #32 extraction site demonstrating an intact inferior alveolar nerve along the cortical plate of bone.

A neurosensory mapping chart can be found in **Appendix 1** for reference.

References

Apostolakis, D. and Brown, J.E. (2012). The anterior loop of the inferior alveolar nerve: prevalence, measurement of its length and a recommendation for interforaminal implant installation based on cone beam CT imaging. *Clinical Oral Implants Research* 23: 1022–1030.

Behnia, H., Kheradvar, A., and Shahrokhi, M. (2000). An anatomic study of the lingual nerve in the third molar region. *Journal of Oral and Maxillofacial Surgery* 58: 649–652.

Chan, H.L., Leong, D.J., Fu, J.H. et al. (2010). The significance of the lingual nerve during periodontal/implant surgery. *Journal of Periodontology* 81: 372–377.

Ghaeminia, H., Meijer, G.J., Soehardi, A. et al. (2009). Position of the impacted third molar in relation to the mandibular canal. Diagnostic accuracy of cone beam computed tomography compared with panoramic radiography. *International Journal of Oral & Maxillofacial Surgery* 38: 964–971.

Hillerup, S. (2008). Iatrogenic injury to the inferior alveolar nerve: etiology, signs and symptoms, and observations on recovery. *International Journal of Oral and Maxillofacial Surgery* 37: 704–709.

Kim, S.T., Hu, K.S., Song, W.C. et al. (2009). Location of the mandibular canal and the topography of its neurovascular structures. *Journal of Craniofacial Surgery* 20 (3): 936–939.

Levine, M.H., Goddard, A.L., and Dodson, T.B. (2007). Inferior alveolar nerve canal position: a clinical and radiographic study. *Journal of Oral and Maxillofacial Surgery* 65: 470–474.

Meyer, R.A. and Bagheri, S.C. (2013). Clinical evaluation of nerve injuries. In: *Trigeminal Nerve Injuries* (ed. M. Miloro). Berlin, Heidelberg: Springer.

Miloro, M. and Kolokythas, A. (2013). Imaging of the trigeminal nerve. In: *Trigeminal Nerve Injuries* (ed. M. Miloro). Berlin, Heidelberg: Springer.

Miloro, M. and Kolokythas, A. (2013). Traumatic injuries of the trigeminal nerve. In: *Oral and Maxillofacial Trauma*, 4e (ed. Fonseca R.J.), 650–682. Philadelphia, PA: Elsevier.

Miloro, M.H.L., Slone, H.W., and Chakeres, D.W. (1997). Assessment of the lingual nerve in the third molar region using magnetic resonance imaging. *Journal of Oral and Maxillofacial Surgery* 55: 134–137.

Pogrel, M.A. (2002). The results of microneurosurgery of the inferior alveolar and lingual nerve. *Journal of Oral and Maxillofacial Surgery* 60: 485–489.

Robinson, P.P., Loescher, A.R., Yates, J.M., and Smith, K.G. (2004). Current management of damage to the inferior alveolar and lingual nerves as a result of removal of third molars. *British Journal of Oral & Maxillofacial Surgery* 42: 285–292.

Rood, J.P. and Shehab, B.A. (1990). The radiological prediction of inferior alveolar nerve injury during third molar surgery. *British Journal of Oral and Maxillofacial Surgery* 28 (1): 20–25.

Ruggiero, S. and Proothi, M. (2013). Guidelines for diagnosis and treatment of trigeminal nerve injuries. In: *Trigeminal Nerve Injuries* (ed. M. Miloro). Berlin, Heidelberg: Springer.

Ziccardi, V.B. and Steinberg, M.J. (2007). Timing of trigeminal nerve microsurgery: a review of the literature. *Journal of Oral and Maxillofacial Surgery* 65: 1341–1345.

Ziccardi, V.B. and Zuniga, J.R. (2007). Nerve injuries after third molar removal. *Oral and Maxillofacial Surgery Clinics of North America* 19: 105–115. vii.

Zuniga, J. (2009). Management of Thrid Molar-Related Nerve Injuries: observe or treat? *Alpha Omegan* 102: 79–84.

Zuniga, J., Meyer, R.A., Gregg, J.M. et al. (1998). The Accuracy of Clinical Neurosensory Testing for Nerve Injury Diagnosis. *Journal of Oral and Maxillofacial Surgery* 56: 2–8.