Lecture Abstract Manual

AOVET Course - Operative Treatment of Veterinary CMF Trauma & Reconstruction (with animal anatomic specimens)

January 22-24, 2018
Oquendo Center
Las Vegas, Nevada

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Operative Treatment of Veterinary Craniomaxillofacial Trauma and Reconstruction

LECTURE ABSTRACTS

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AOVET NORTH AMERICA

Operative Treatment of Veterinary Craniomaxillofacial Trauma and Reconstruction

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Maxillofacial Growth and Development: Effects of Trauma on Growing Structures

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Maxillofacial Growth and Development: Effects of Trauma on Growing Structures

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Learner Objectives:

- Recognize the embryologic origin of the structures of the maxillofacial region
- Describe the formation and developmental growth mechanisms of the mandible and maxilla
- Discuss the impact that developmental signaling and occlusion play in growth of the mandible and maxilla
- Describe the impact that trauma can have on developing teeth
Neural crest cells provide the connective tissue necessary for embryologic development of the cranium and face. Branchial (pharyngeal) arches are developmental structures consisting of mesodermal and neural crest cells. The first branchial arch gives rise to the mandible and maxilla.

When developing structures originate in the form of cartilage and the layers of chondrocytes become so thick that the external nourishment cannot take place, reorganization occurs and an internal blood supply develops. When this develops, these areas become centers of ossification where cartilage becomes ossified (endochondral ossification). Endochondral ossification represents how the canine and feline chondrocranium forms. The cranial vault and maxilla and mandible form by intramembranous ossification where bone matrix is directly secreted by connective tissues. Continued osteoblastic differentiation in the periosteum and endosteum result in additional bone deposition.

Regulation of maxillofacial growth is a dynamic process impacted by hormones, genetics and the active forces of the teeth and muscles of mastication. Growth of the mandible is not controlled by the condyle. Muscular attachment and forces acting on the TMJ impact growth. Forces placed on the TMJ restricts growth while lack of forces encourage mandibular growth. In addition, the lips play a role on the centripetal pressure on the dental arches while the tongue plays an equivalent and opposite force. An abnormal balance between these two forces can result in growth abnormalities. This can be particularly evident in children who have suffered craniofacial injuries that result in developmental abnormalities. Dogs and cats having a profound dental interlock (relationship between mandibular canine teeth and maxillary third incisors and canine teeth) help coordinate maxillary and mandibular growth.

In genetic studies in the 1930’s, deliberate cross breeding between skull shapes revealed that as dogs were selectively bred to have brachycephalic head shapes from mesocephalic head shapes, the muzzle length became shorter without a proportional change in tooth size. This caused rotation, crowding and changes in occlusion. These genetic studies showed that tooth form/shape was the most stable characteristic of the dog skull. Genetics were shown to independently control the maxilla and mandible, and independently control tooth size from the maxilla and mandible. Cephalometric studies in dogs have shown that the maxilla and mandible were independent in size and that the size of the dental arch demonstrated larger variation in size than did the size of teeth.
Three theories exist for control of craniofacial development. Maxillofacial growth potential is thought to be controlled by: the actual bone, the cartilage or the immediately surrounding soft tissue structures. While cartilage and immediately surrounding soft tissues seem to be the most plausible determinants of growth, it is accepted that the functional demands on the bone in combination with the soft tissues control development.

Cartilages that give rise to development of the mouth are the palatoquadrate cartilage giving rise to the maxilla and Meckel’s cartilage forming the mandible. Most of the mandible forms from intramembranous bone formed within the soft tissues adjacent to the cartilage. Maxilla and mandible both develop by intramembranous ossification. The maxilla grows by appositional bone growth at the attachment of the maxilla to the cranium and by surface remodeling. Mandibular bone forms by intramembranous, interstitial and appositional bone growth. Mandible grows by endochondral ossification at the mandibular condyle and appositional growth stemming from the periostium surfaces.

A majority of mandibular growth occurs from bone growth along the caudal aspect. Supporting evidence that growth occurs entirely from growth of the caudal mandible is supported by one study that evaluated the incisor to mandibular first molar distance and found no change in distance between 3 and 6 months of age. Studies in mice using radiolabels attached to developing dental tissue demonstrated that the location of caudal cheek teeth extended almost completely to the caudal edge of the developing mandible. Through simultaneous appositional bone growth and resorption, those tooth structures continued development and eruption into what forms the caudal mandibular body. In dogs, it is believed that growth almost exclusively originates from the caudal mandible starting at day 50.

The mandible gains height through cartilage replacement at the condylar process and bone deposition along the ventral border of the caudal mandible. Mandibular height increases through appositional bone growth along the ventral border and alveolar crest at the time of tooth eruption. The reality of mandibular growth is not that it grows down and away from the base of the skull but instead pushes upward and caudally against the TMJ resulting in translation. Mandibular bone growth has shown to be rapid early in skeletal growth but by 6-7 months of age the mandible appears to be relatively unchanged thereafter. This correlates with the cephalocaudal gradient of growth proposed in humans where it is believed that the closer to the calvarium a bone is, the less growth potential it has.

From: Profitt WR. Concepts of growth and development.
Growth of the nasomaxillary complex is believed to occur by two mechanisms - natural growth by the calvarium resulting in forward displacement of the maxilla, and appositional growth at the suture lines stimulated by the surrounding soft tissue. The maxillary sutures responsible for growth are the incisivo-maxillary suture line and the palato-maxillary suture line. The palato-maxillary suture line plays an active role in growth early in development, but its contribution diminishes with age while the contribution of the incisivo-maxillary suture increases. After eruption of the permanent teeth any remaining growth of the maxilla originates from the incisivo-maxillary suture line. Increase in the maxillary width occurs at the intermaxillary suture line and is relatively unchanged after 22 weeks of age.

Measurements and tracking of developing tooth germ have also been studied in dogs. Additional evidence that the teeth are disproportionately large in smaller dogs has been shown in the tooth to arch ratio. This ratio has been shown to be higher in small dogs predisposing them to crowding. In general, through development and growth, this ratio is higher early on and decreases during development. This explains why some dogs may demonstrate crowding at a very young age and seem to “grow” out of it.

Occlusal forces have also been shown to impact mandibular and maxillary bone growth. In two dogs, it has been shown that extracting teeth during development impacted ipsilateral mandibular bone height and underdevelopment of the condyle. No studies with large groups of dogs have been done nor do specific measurements exist, but there does appear to be reasonable support to suggest that occlusion impacts alveolar bone development and how occlusion impacts jaw growth. The degree of muscle activity is confirmed to be highest in areas of attachment of the most powerful muscles. And muscle activity is the greatest extrinsic factor affecting jaw length development.

In addition to the disruption of mandibular growth possibly impacting occlusion, developing tooth structures are susceptible to inflammation or trauma which can impact their maturation. It has been well established that dogs under 12 months of age are over represented in the craniomaxillofacial trauma population. Unerupted developing tooth structures in the fracture line should be maintained through the healing period and monitored for the impact on tooth maturation and eruption. An exception is made for these unerupted teeth if there is evidence of infection or nonvitality in the fracture location. Instances where even minor trauma is sustained by juvenile patients, permanent tooth buds can be displaced or severely affected resulting in impaction, dentigerous cyst formation, malformed crown/root structure and possible induction of benign dental tumors such as compound odontomas.
References:


Fundamentals and Limitations of Maxillomandibular Fixation (MMF) / Bonding and Removal (Tooth Conditioning)

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Fundamentals and Limitations of Maxillomandibular Fixation (MMF) / Bonding and Removal (Tooth Conditioning)

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Learner Objectives:

- Describe the principles and appropriate indications for maxillomandibular fixation
- Differentiate between the various types of materials necessary for tooth conditioning and composite bonding
- Demonstrate how to place a patient into maxillomandibular fixation and remove the appliance
Maxillomandibular fixation (MMF) can serve as a useful mechanism for restoring oral fracture patients to normal occlusion. By returning the patient into normal occlusion, fracture fragments should be reduced to a functional apposition resulting in the maintenance of that occlusion after healing. Use of a loose-fitting muzzle may be the least expensive form of MMF. This option relies on tooth structures to guide the lower jaw into a functional, atraumatic position. The instability of fracture fragments with this form of MMF risks exuberant callus formation, nonunion or fibrous union. A more stable form of reduction includes temporary fixation of the maxillomandibular relationship using bonding materials to immobilize the mandibular and maxillary canine teeth. MMF using this technique is designed to approximate the fracture fragments into an orientation that will leave the patient functional after healing, as well as to reduce micromotion enough to reduce the size of callus formation. The canine cusp tips are closely approximated leaving 1cm of space between the incisors – this should be enough space for the animal to be able to lap water and liquid food. Immobilization should not exceed 3-5 weeks without reinstituting some sort of physical therapy in order to prevent functional ankylosis from developing due to restricted motion of the TMJ. MMF may be most appropriate for fractures that are already reduced or stabilized by surrounding soft tissues. Specific fractures that may be most appropriate for MMF include: stable and nondisplaced fractures, fractures of the ramus and condylar neck fractures. It is in my opinion that if pain could be reasonably managed, it is appropriate to consider using MMF when finances are an issue and euthanasia is the only other option. Clients must be aware that MMF carries a greater risk of complications with healing compared to more semi-rigid or rigid forms of fixation.

Using dental composites to place a patient into MMF should be done with several major considerations in mind. Firstly, consideration should be made to avoid the risk of developing false ankylosis due to the restrictions on TMJ motion. Limiting the range of motion of the TMJ for 3, to no more than 5 weeks should reduce the chances of ankylosis. Depending on the location of the fracture, extent of the injury, and age of the patient, the patient may need to graduate out of composite fixation and into a loose-fitting muzzle to maintain occlusion and provide supplemental support.
Consideration should also be given to follow-up anesthesia episodes. Different techniques can be implemented to aid in the removal or breakdown of composite for anesthesia. Creating scores in the composite or superficially marking the composite between the tooth cusps at the time of placement can facilitate easier scoring and breaking the MMF. Haphazard or hasty removal of composite can result in iatrogenic enamel damage. It would be wise to include unintended tooth damage as a potential complication when counseling clients. Otherwise, anesthetic induction is followed by immediate severing of the composite bridges and endotracheal intubation. An alternative may be to endoscopically intubate the patient. Once intubated and stable, additional composite can be removed from the tooth crowns by creating longitudinal scores in the composite and using calculus removal forceps to free the composite from the tooth surface. By acid etching and applying adhesive to select areas of the crown rather than the entire crown, composite removal may be easier. Be warned, decreased adhesive surface area results in decreased adhesion!

**Tooth Conditioning:**

Four important properties necessary for dental adhesives are: wetting, interpenetration, micromechanical interlocking and chemical bonding. Wetting is the property of a material to contact another material and spread across its surface. Enamel and dentin are hydrated tissue structures, which are hydrophilic and therefore require a resin material that is also hydrophilic. These bonding materials create a “hybrid” layer by coating the enamel or dentin and upon curing, creating a hydrophobic surface conducive to the wettability and adhesion of hydrophobic materials (composites).

Acid etching is an effective way of enhancing mechanical bonding. Etching has expanded the use of resin based restorative materials because of the strong bond created between resin and enamel. Without improvements and advancements in bonding, composite materials would not be able to resist leakage of fluid at the tooth-composite interface, which undermines bond strength. Etching enamel surface increases microporosities and roughness which increases surface energy - a quality describing the interaction between the resin material’s affinity to spread across and interdigitate into those microporosities. An etched surface enables resin to flow into surface microporosities and form 10-20um resin tags. 37% phosphoric acid is used most commonly with concentrations greater than 50% generating a layer of monocalcium debris on the tissue surface inhibiting dissolution. It is important to avoid the creation of bubbles on the enamel surface when etching since those surfaces will not be etched. Most teeth should only undergo 15 seconds of etching time followed by 20 seconds of thorough rinsing. The tooth surface is then air-dried and should appear white and frosty. It is important to maintain a dry tooth surface after etching until the adhesive is applied. Brief contact with blood or saliva will greatly reduce surface energy of the roughened enamel and significantly reduce the resin’s ability to

![Enamel surface under scanning electron microscopy after being treated with phosphoric acid. From: Phillips’ Science of Dental Materials 11th ed pg. 384](image-url)
wet (spread across) the surface. Oil from the air/water syringe can also contaminate the etched surface. If contamination is suspected, debris should be removed and the surface re-etched for 10 seconds.

Historically, bonding agents were specific to enamel. Advances in chemical engineering modified these agents to be less hydrophobic and better able to wet the surface of dentin. These materials are used today because of their added advantage to bond to both enamel and dentin. Dentin bonding products were developed to combat the increased organic component and water contained in dentin. These products showed universal ability to bond to acid etched enamel and dentin surfaces. The key to the success of these products was the development of materials that contained hydrophilic monomers capable of flowing and interdigitating with the collagen tags while also containing hydrophobic monomers that would move away from the treated tooth surface. This facilitates the bonding agent’s ability to chemically adhere with the hydrophobic composite matrix. These bonding agents are described in generations with the earliest being least effective. It is important to understand which system you are using to ensure that the proper steps are taken to condition the tooth surface to maintain a proper bond.

First and second-generation adhesives: These materials used silane coupling agents to bond inorganic filler to the resin matrix in composites. Further iterations included modifications to better bond to dentin. Neither of these generations of material was clinically successful. Third generation adhesives: These materials included an acid designed to react with Ca^{2+} ions and reduce interaction with the smear layer. These products required 4 steps involving: a conditioner (acid), a primer, an adhesive and resin composite. Fourth generation adhesives: There was a shift away from fears that etching dentin was detrimental to the pulp. This was the underlying reason for changes in chemicals used in this generation of adhesives. Tooth surface is etched and rinsed in this system but the conditioned surface is not desiccated for fear of the exposed collagen mesh would slump and result in difficulty of the primer infiltrating the collagen surface. This generation of products required etching, rinsing, drying, moistening, slightly drying, applying a primer, drying thoroughly, adhesive application and light curing, composite application and light curing. These products were the first to introduce the total etch principles (to both enamel and dentin) followed by rehydrating the dentinal collagen and the “wet” bonding process. Fifth generation adhesives: This generation of materials attempted to reduce the number of steps in fourth generation products with the hope there would be less room for technical human error. Products which combine the conditioner and primer (self-etching primer) or combining the primer and adhesive (self-priming adhesive) were introduced. Proposed products that include all components (self-etching/priming/adhesive) in one solution are being researched and would be considered sixth generation systems. Early indications show that there may be potential for sufficient bond strength to dentin but not enamel.
**Composites:**

Materials containing inert filler particles (quartz powder) reduce curing contraction by taking up space and not participating in the setting reaction. It is important that these filler particles create bonds to the polymer resin to maintain structural strength.

Composites contain a resin matrix, inorganic filler materials and a coupling agent. An activator-inhibitor mixture is necessary to take a semi-liquid, moldable material and transform it into a hardened material. Of the resin matrix components in composites, bisphenol A glycidyl methacrylate (bis-GMA), triethylene glycol dimethacrylate (TEGDMA) and urethane dimethacrylate (UDMA) are the most prevalent ingredients used today. Before activation and polymerization, monomers are weakly held together by van der Waal forces. Once polymerization occurs, covalent bonds tightly bond the monomers. In light curing systems, polymerization of the monomers occurs with the material closest to the light activator condensing and polymerizing first. Shrinkage of material therefore occurs towards the light source. Multiple particle sizes are used in most dental composites to maximize the amount of filler into a resin matrix. Quartz is commonly used filler that adds great strength to dental composites.

Polymerization occurs by a series of chemical reactions where monomers (small molecules) are bonded to form one large polymer (macromolecule). A benefit of polymers is that their size can almost become limitless and forms a structure that is cross linked and of variable chain length. Addition polymerization is the chemical reaction whereby monomers join onto the end of chain to form a polymer.

Chemical cure systems are formed by the mixing of two pastes. When the pastes are mixed an initiator and amine activator to form free radicals, which initiate additive polymerization. Light cure composites rely on visible blue light activated system. In these systems, a photosensitizer and amine initiator are included in one paste. When exposed to the blue light spectrum of light (460-480nm), the photosensitizer reacts with the amine to generate free radicals in turn resulting in addition polymerization. Camphorquinone is a commonly used photosensitizer. Inhibitors may be added to composite resins to prevent spontaneous chain polymerization. If free radicals are formed and absorbed by the inhibitor, polymerization stops. If the inhibitor is used up or destroyed in a curing process, addition polymerization continues.

Chemical activation of composites is referred to as cold-cure or self-cure composites. The operator has no effect on curing time once mixing of the pastes occurs. The depth of cure for light cure composites is restricted based on light penetration. Curing (exposure to the blue light should occur in 2mm thick increments and be exposed to the light for 40 seconds or less depending on manufacture’s recommendations). Light curing lamps (light guns) emit a light source within the 460-480nm wavelength spectrum. Curing lamps are being developed with increasing intensities that results in certain curing lamps generating shorter necessary curing times and the capacity to cure to greater depths. Due to dissipation of photons at greater depths, insufficient photo activation may occur at depths
greater than 3mm at a recommended exposure time- greater exposure times may be necessary which offsets the advantages of photo curing shallower depths more quickly.

As composite material cures (light cure or chemical cure) a layer remains on the surface known as the oxygen inhibiting layer. In the presence of oxygen, composite is monomers and resin matrix is unable to polymerize. Layering additional composite onto this surface provides an ideal surface for continued polymerization of the unit. Even after polishing or material removal, additional composite can be added and cured. Over time, fewer and fewer unreacted methacrylate groups remain and the potential for cross-linking and addition of new monomers to penetrate into the matrix decreases. Composite segments that fracture well after initial curing can be reapplied with a bonding agent and composite reapplied. The bond strength between this new composite and the cured composite should be viewed as having less than half the original composite’s strength. In one study evaluating light curable composites compared to chemical cure composites for bonding of canine teeth in cats, it was found that light cure composites were stronger than chemical cure. Additionally, light cure composite resins took longer to remove and were associated with a greater number of complications associated with removal.

**MMF Application and Removal**

Once under anesthesia, the canine teeth should be scaled and polished to remove plaque and calculus. Polishing should be performed with regular flour of pumice. Oils associated with polishing pastes interfere with dental adhesives bonding to tooth structure. The canine teeth are commonly used for maxillomandibular bonding. The teeth should be conditioned/etched/primed according to the manufacturer’s instructions of the products you are using. Once the adhesive has been applied and cured, the canine teeth should be placed into the normal position and the cusp tips approximated. Self-curing or light curable composite can be applied to the crown surface and allowed to cure or light cured while being held in place. Light curable composites should be cured in stages and the depth of the composite should be limited to 2mm thick between curing. If using self-curing composites, 1cc syringe casings or IV tubing can be trimmed and placed over the canine tooth cusps to serve as a mold. It may be advisable to score or mark with an indelible marker the location between cusp tips to facilitate removal.

Initial removal of MMF is typically done under heavy sedation or immediately after anesthetic induction agent is given. With a diamond bur on a high-speed handpiece the composite can be cut or scored. Using calculus removal forceps or large wing tipped elevators the composite can be fractured in the weakened area. After intubation, additional composite can be removed by placing superficial longitudinal scores and pried off in segments using dental elevators, ronguers or calculus removal forceps. The crowns should be ultrasonically scaled and polished once the entire composite is removed. Any enamel damage should be documented with dental radiographs, the client informed and treated with dental restorative materials (some of which we have just discussed.)
References:


Dentoalveolar Trauma

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Learner Objectives:

- Describe essential anatomy of the teeth in cats and dogs
- Diagnose tooth wear, tooth fracture, tooth displacement injury, and teeth in jaw fracture lines
- Recognize clinical and radiographic signs of endodontic and periapical disease
Dentoalveolar Trauma

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Introduction

Trauma is usually the cause of fracture of canine and carnassial teeth in the dog. Tooth resorption is often a predisposing factor in crown fracture of cats, with root fragments remaining in the jaws. Tooth displacement injuries result from blunt trauma in horizontal or vertical direction and cause damage to the attachment apparatus and loss of blood supply to the pulp.

Bacterial infection occurs if tooth fracture has exposed the pulp cavity, resulting in pulpitis and progressing to pulp necrosis. Periapical disease may develop, leading to facial swelling and sinus tracts. Endodontic therapy is then required to prevent tooth loss. Pulpitis and pulp necrosis can also occur without obvious pulp exposure, e.g., after a blow to a tooth with leakage of blood into the pulp cavity, tooth displacement injuries, or excessive heat or cold to the tooth. Dental radiography, special instruments and materials, knowledge of various techniques, and sufficient operator skills are required to perform endodontic and restorative procedures.

Tooth fractures are classified based on location (crown, crown-root, or root) and whether or not pulp exposure has occurred (uncomplicated [without pulp exposure] or complicated [with pulp exposure]). Crown-root fractures that extend significantly subgingivally into the root must be treated with periodontal surgery prior to endodontic therapy. Root fractures may not require treatment if they are in the apical half of the root of a non-mobile tooth. Extraction is the treatment of choice for teeth fractured along the long axis of the tooth root(s) and teeth with advanced root resorption.

Essential Anatomy

The tooth consists of a crown and one or more roots. The bulk of the tooth is made up of dentin, which is produced by odontoblasts of the pulp. The dentin of the crown is covered by enamel, and that of the root is covered by cementum.

The pulp is the innermost part of the tooth, consisting of undifferentiated mesenchymal cells, functional cells (fibroblasts and odontoblasts), blood and lymph vessels, and nerves. The pulp cavity consists of the pulp chamber in the crown and the root canal in the tooth root. Odontoblasts line the inside of the pulp cavity, producing predentin which later becomes mineralized dentin.
The tooth ‘grows’ towards the inside. The outermost dentin is the ‘oldest’ produced dentin, while the innermost dentin is the ‘youngest.’ Domestic carnivores should have a full set of permanent teeth at 6-7 months of age. However, root lengthening and apex closure (apexogenesis) require several more months to complete. Dentin apposition along the inside of the pulp cavity continues throughout life, unless irreversible pulpitis or pulp necrosis occurs.

Therefore, teeth of young adult animals have a fairly wide pulp cavity. In old animals, the pulp cavity is usually very narrow. The narrower the pulp cavity, the thicker are the dentinal walls, and thus the stronger is the tooth. Comparing the radiographic appearance of the pulp cavity between ipsi- and contralateral teeth is a very effective means to determine pulp vitality of teeth with suspected endodontic pathology.

**Tooth Wear**

Abrasion is tooth wear caused by contact of a tooth with a non-dental material (such as a tennis ball or cage bars). Attrition is tooth wear caused by contact of a tooth with another tooth (such as when a maloccluding tooth contacts another tooth). Tertiary dentin is dentin produced as a result of a local insult such as tooth wear. It can be reactionary (produced by existing odontoblasts) or reparative (produced by odontoblast-like cells that differentiated from pulpal stem cells).

Sclerotic dentin is somewhat transparent dentin characterized by mineralization of the dentinal tubules as a result of an insult or normal aging. If tooth wear removes enamel and dentin faster than odontoblasts of the pulp can form dentin, the pulp may either succumb to prolonged chronic inflammation or become exposed, inflamed and necrotic.

**Tooth Fracture**

Tooth fractures are classified based on the fracture location (crown, crown-root, or root) and whether the pulp is exposed (uncomplicated or complicated; there is debate about whether the current nomenclature should be amended, as the term “uncomplicated” could mistakenly be interpreted as that there are no negative consequences for endodontic health and that treatment may not be needed). Enamel infraction refers to an incomplete fracture (crack) of the enamel without loss of tooth substance. An enamel fracture is a fracture with loss of crown substance confined to the enamel only; the consequences usually are minimal.

An uncomplicated crown fracture refers to a fracture of the crown that does not expose the pulp. Near pulp exposure means that a thin layer of dentin separates the pulp from the outer tooth surface. If dentin is exposed but not yet the pulp, odontoblasts may react by producing tertiary dentin. It is also possible that bacteria could pass through dentinal tubules to the pulp to cause an infection of pulp tissue. A complicated crown fracture is a fracture of the crown that exposes the pulp. A crown-root fracture is a fracture that
involves the crown and root(s) of the tooth; it can be uncomplicated or complicated. A root fracture is a fracture involving the root (far more common with pulp exposure than without).

Canine tooth fractures are usually due to hit-by-car trauma, falls from heights, kicks and hits. Certain working dogs are more prone to fracture of canine teeth if their distal tooth surfaces are weakened by wear from chewing on cage bars. Carnassial tooth fractures (primarily the maxillary fourth premolars and less so the mandibular first molars) in dogs are often caused by chewing on very hard objects. Tooth resorption is typically the cause of crown fracture in cats, with crown-root or root remnants being retained in the alveoli.

**Tooth Displacement Injury**

Tooth luxation refers to a clinically or radiographically evident displacement of the tooth within its alveolus, while tooth avulsion is a complete extrusive luxation with the tooth out of its alveolus. Lateral and incomplete extrusive luxation in dogs typically is associated with alveolar fracture, while in cats it more likely occurs after alveolar bone expansion, infrabony pocket formation, and abnormal tooth extrusion, eventually causing inability to fully close the mouth. Intrusive luxation of canine teeth into the nasal cavity may sometimes occur in patients with severe periodontal disease.

**Endodontic and Periapical disease**

Pulpitis can either be reversible or irreversible. Dystrophic mineralization of the pulp may occasionally occur as a result of pulpitis, leading to regional narrowing or complete disappearance of the pulp cavity. This should not be confused with pulp stones which are intrapulpal mineralized structures unrelated to current disease.

Pulp necrosis is a sequel of an untreated irreversible pulpitis, a traumatic injury or events that cause long-term interruption of the blood supply to the pulp. A tooth with necrotic pulp is called a non-vital tooth. Infection and inflammation of the pulp can spread through the apical and non-apical ramifications into the periapical region, furcation area, and other areas of the periodontal ligament space. Endodontic disease may result in crown discoloration (pink, red, purple, gray, or brown). One study revealed that over 90% of teeth with crown discoloration are non-vital.

A periapical cyst (also known as radicular cyst) is an odontogenic cyst formed around the apex of a tooth after stimulation and proliferation of epithelial rests in the periodontal ligament. It is a very rare consequence of endodontic disease. If an affected tooth is extracted without removing the cyst lining around the root apex, a residual cyst remains.

A periapical granuloma refers to a chronic apical periodontitis with accumulation of mononuclear inflammatory cells and an encircling aggregation of fibroblasts and collagen that on diagnostic imaging appears as diffuse or circumscribed radiolucent lesion. This is
the most common periapical pathology recognized in dogs and cats. It may radiographically be indistinguishable from a periapical abscess.

A periapical abscess is an acute or chronic inflammation of the periapical tissues characterized by localized accumulation of suppuration. Clinical signs include facial swelling, sinus tracts, pain, and fever and general malaise in more acute and advanced cases. An intraoral sinus tract is a pathological communication between tooth, bone or soft tissue and the oral cavity. An orofacial sinus tract is a pathological communication between the oral cavity and face. A Phoenix abscess is an acute exacerbation of chronic apical periodontitis.

Osteosclerosis is excessive bone mineralization around the apex of a vital tooth caused by low-grade pulp irritation. The affected tooth is asymptomatic and does not require endodontic therapy. Condensing osteitis, however, is referred to as excessive bone mineralization around the apex of a non-vital tooth caused by long-standing and low-toxic exudation from an infected pulp. An affected tooth requires endodontic therapy. Alveolar osteitis is an inflammation of the bone in immediate proximity to the alveolus and may occur when a blood clot dislodges in an unsutured tooth extraction site. Osteomyelitis and osteonecrosis refer to localized or wide-spread infection and necrosis of the bone and bone marrow, respectively.

**Conclusion**

Dentoalveolar trauma includes tooth wear, tooth fracture, and tooth displacement injury. There are distinct clinical and radiographic signs for each condition. Treatment depends on the extent of trauma and whether endodontic and periapical disease resulted from it.
Maxillofacial Trauma Imaging Considerations

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Learner Objectives:

- Describe the pros and cons of the various diagnostic imaging modalities
- Apply the basics of CT and CBCT interpretation, including 3D imaging
- Apply the indications for 3D printing
Maxillofacial Trauma Imaging Considerations

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We recommend a multidisciplinary approach for systemic stabilization after trauma. Specifically, oral and maxillofacial (OMF) trauma patients are evaluated by emergency and critical care, ophthalmology and neurology clinicians prior to anesthesia and surgical intervention. Diagnostic imaging is pursued once the animal is cleared for anesthesia. This is typically combined with surgical repair under the same anesthetic period.

**Dental Radiography**
Dental radiographs provide fine detail of the teeth, alveolar margin and trabecular bone. They are therefore indicated to assess concomitant dental disease and dental trauma, bone fracture lines and bone quality.

**Skull Radiography**
Skull radiographs are of limited diagnostic value in OMF trauma and rarely used. However, skull radiographs may be indicated to screen for temporomandibular joint (TMJ) involvement.

**Computed Tomography**
Computed tomography (CT) is becoming more readily available and affordable in veterinary medicine. It is indicated in OMF surgery in trauma cases to visualize the maxillofacial structures and TMJs. The use of CT with contrast medium is indicated for soft tissue conditions, such as masticatory muscle myositis. The CT scan should be acquired with a slice thickness as thin as possible.

**Cone-Beam Computer Tomography**
A recent advance in veterinary dental and maxillofacial imaging the cone-beam computed tomography (CBCT). With this imaging modality images are obtained with very high resolution. These can then be imported into special imaging software to evaluate the teeth and maxillofacial structures in great detail.

**Tridimensional Imaging and Printing**
Advanced mandibular and maxillofacial reconstruction surgery in veterinary medicine is becoming more common and receiving wider acceptance. However, these challenging cases require special preoperative planning due to the region's complex anatomy. The use of tridimensional (3D) imaging and, more recently, 3D printing as surgical planning
modalities for mandibular and maxillofacial surgery in dogs and cats were recently introduced.

The use of 3D imaging following CT or CBCT is the standard of care at our institution and is performed by the attending surgeon. Several software programs are available for manipulation of DICOM files created by CT or CBCT for volume rendering and 3D imaging. This is routinely indicated for maxillofacial trauma cases as well as for oral tumor cases with bony involvement. It is also indicated for palatal defects, to compare the size and shape of the osseous defect with the soft tissue defect.

Having a 3D model provides the surgeon with the ability to perform precise preoperative planning and practice a virtual osteotomy and design a patient-specific implant preoperatively. The 3D printing of the affected skull overcomes this limitation and allows for a tangible understanding of the disorder and the precise surgical treatment. This may be further justified as precise presurgical planning may reduce the surgery time and allow for a reduction in overall surgical costs. They are also excellent tools for client and student education. Patients with complex mandibular and maxillofacial fractures may also benefit from 3D printing. The 3D printed skulls can be used for presurgical planning, plate selection and pre-bending of the plates, which saves on anesthetic time. For defect non-union mandibular fractures, the intact mandible can be mirrored for highly accurate pre-bending of the plate destined for the affected side.

Corrective ostectomies for ankylosis and pseudoankylosis of the temporomandibular joint can be very complex and not only involve the condylar process but also the coronoid process, zygomatic arch, and temporal bone. Precise preoperative planning and practicing a virtual osteotomy is possible with 3D printed models.

References

Winer JN, Verstraete FJM, Cissell DD, et al. 2017 The application of 3-dimensional printing for preoperative planning in oral and maxillofacial surgery in dogs and cats. Veterinary Surgery (Epub ahead of print)
Mandible: Anatomy, Biomechanical Principles, Surgical Approaches

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Mandible: Anatomy, Biomechanical Principles, Surgical Approaches

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Learner Objectives:

• Identify salient and important anatomical features of the mandible as they relate to the reconstruction and repair of mandibular fractures
• Explain the importance of preservation of injured or traumatized teeth with regards to fracture repair and describe situations where removal/extraction of teeth is recommended over preservation
• Discuss the biomechanical forces present in the intact and fractured mandible and apply this understanding to neutralization of these forces with our surgical implants/fixation
• Property position and secure the patient with a mandibular fracture on the surgical table, describe techniques for endotracheal intubation which allow assessment of dental occlusion during surgical repair, ad identify the most appropriate surgical approach to the mandible for a given fracture(s)
Mandible: Anatomy, Biomechanical Principles, Surgical Approaches

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Anatomy

Most of the dorsal two-thirds of the body of the mandible is occupied by dental roots. The ventral third includes the mandibular canal, containing the inferior alveolar nerve and associated blood vessels, the inferior alveolar artery and vein. The inferior alveolar nerve provides sensory innervation for the teeth and leaves the bone through three mental foramina as the mental nerves. These nerves are sensory to the soft tissues of the rostral part of the lower jaw. The blood vessels in the mandibular canal are most important as they supply all of the teeth by way of small dental branches (rami dentales) entering the apical foramina and the bone itself. Ventral to the mandibular canal there is only a single layer of dense cortical bone.

The lower jaw consists of two mandibles, joined at the symphysis, which consists of a synchondrosis between the slightly irregular bony surfaces. The symphysis remains a true joint throughout life in the dog and cat. The term symphyseal separation is therefore more accurate than symphyseal fracture. The mandible consists of a body (often incorrectly referred to as the horizontal ramus), which is the tooth-bearing part, and a ramus, which is the caudal, non-tooth bearing part. The body of the mandible can further be divided into an incisive part and a premolar/molar part. Fractures involving the incisive part are typically discussed together with symphyseal separations, while discussions of fractures of the body of the mandible focus on the premolar/molar part of the mandible. The ramus of the mandible contains three prominent processes: the coronoid process on the dorsal aspect, the condylar process caudally, and the angular process caudoventrally.
Initial Patient Assessment

A mandibular fracture usually is an obvious lesion; a potential pitfall exists in that other less obvious but equally serious problems may go unnoticed. The diagnosis of a fracture of the mandible usually can be made by inspection and/or palpation. The ventral borders of both mandibles should be gently palpated for asymmetry and discontinuity by placing the fingers in the patient’s mouth adjacent to the alveolar margin. Some patients will permit gentle opening of the mouth, which will allow a visual assessment. As most fractures are open to the oral cavity, any discontinuity in the dental row, or gingival laceration, or bony discontinuity usually is easily palpable or visible. Fractures caudal to the teeth, however, are much more
difficult to assess on physical examination. The nature and extent of the fracture is best assessed under general anesthesia by gentle palpation and diagnostic imaging.

**Teeth in the Fracture**

Trauma to the teeth frequently occurs with maxillofacial fractures. Fracture of a tooth may expose the pulp cavity, or compromise the blood supply as a result of a fracture adjacent to the tooth root. Significant patient morbidity will result if such lesions are not appropriately addressed. An increased frequency of complications with fracture healing has been observed when teeth are removed due to their involvement with fractures of the dental alveoli. Removal of teeth may increase complications due to disruption of the blood supply and iatrogenic trauma to the adjacent tissues, including: further displacement of the fractured bone fragments, elimination of occlusal landmarks useful in realigning bone segments to allow functional occlusion, elimination of available structures for use in the fixation of bone fragments, and creation of a large bony defect adding to the difficulty of the reduction and stabilization. Several studies in humans have long established that teeth remaining in a fracture line did not increase the complication rate or morbidity associated with mandibular fractures. Preservation of teeth involved within a fracture line in mandibular fractures also has been reported to have a favorable prognosis if optimal reduction and stabilization of the jaw has been achieved. Therefore, removal of teeth is not advised unless involved teeth are fractured (even here universal removal is not recommended if the tooth contributes to the stabilization, i.e., the fracture of the tooth does not involve the root) or loose and cannot be stabilized. One situation in which teeth in a fracture line should be removed is when there is periapical abscessation or advanced periodontitis which has contributed to pathological fracture of the mandible. It is preferable to allow long-term observation to assess the final outcome of possible pulpal damage in situations in which the vitality if a tooth is in question. Current recommendations by human oral surgeons are to preserve teeth whenever possible in the presence of a fracture. Preservation of teeth in small animals is similarly recommended – especially considering the much greater relative area of bone that the teeth occupy in small animals, and their greater importance of maintaining bony continuity/stability.

**Biomechanics**

An understanding of the functional anatomy is the prerequisite for successful application of the fracture fixation devices in the unfamiliar location of the mandible. These biomechanical principals must account not only for the very large forces generated, but also the position of the teeth that can – and often do – interfere with implant application. Bending forces are the primary distracting forces acting on the mandible that must be neutralized. A continuum of tensile to compressive stresses exists from one side of the bone to the other during bending stress. Maximal tensile stresses are present at the oral (alveolar) surface, and maximal compressive stresses are present at the aboral (ventral) surface; therefore, distraction is created at the oral margin. These bending moments increase from caudal to cranial; furthermore, shear forces are maximal at the ramus, while rotational forces are most prominent rostral to the canine teeth – and maximal at the mandibular symphysis. Bending moments, however, remain as the most significant force that must be neutralized due to the anatomic configuration of a long lever arm with absence of supplemental support.
Application of the fixation must consider the tension and compression surfaces of the bone. All fixation devices are strongest in tension (stresses parallel to the longitudinal axis of the implant); therefore, they should be placed along the lines of tensile stress, or on the tension surface of the bone. In cases of mandibular fractures, this location is along the alveolar border; however, the presence of the teeth will interfere with this most optimal biomechanical location.

Surgical Management

Anesthetic and Surgical Positioning

Treatment of maxillofacial trauma poses unique problems of appropriate surgical access. Special attention to maintaining an adequate airway, including appropriate tracheal access, and proper patient positioning so as to secure the head and simultaneously permit unimpeded approach to the bones of the mandible must be obtained. Routine induction and endotracheal intubation per os for anesthetic maintenance and surgery is performed in the management of simple fractures (large fracture fragments without comminution). Anatomic re-alignment and reduction of the fracture fragments, rather than dental occlusion, is used to determine the accuracy of surgical reduction in these instances. Alternatively, dental occlusion must be used to access the accuracy of the surgical reduction in cases of severely comminuted fractures or those with bone loss. In these instances, the endotracheal tube must be replaced so as to by-pass the mouth (endotracheal intubation via pharyngotomy) so that the mouth can be fully closed to assess occlusion.

Patient positioning is performed such that the head is reversed and at the opposite end of the surgical table from the anesthetic machine in order not to limit surgical access. Additionally, the head must be securely fixed to the table so as to remain stable during surgical manipulation; this is accomplished by placing the patient in dorsal recumbency, then taping the maxilla to the table with waterproof tape that traverses across the upper
canine teeth (the ventral mandible is prepped, along with the intraoral portion of the tape and oral cavity). The tongue must be reflected caudally (into the pharynx) to allow an unobstructed intraoperative assessment of occlusion. Such surgical access and patient positioning complicates anesthetic monitoring as the routine evaluation of eye position and reflexes and assessment of jaw tone is not possible. Therefore, greater reliance is placed on monitoring the heart rate and rhythm, respiratory depth and rate, pulse character, and blood pressure.

Aseptic preparation of the surgical field, including the mouth, is accomplished by routine methods. The eyes must be protected with an ophthalmic ointment. In simple fractures, where endotracheal intubation per os is performed, the oral cavity is not included in the draping. In those cases where occlusion is to be used to assess the reduction, and the endotracheal tube bypasses the mouth, draping is performed to include full access to the oral cavity.

Surgical Goals

Proper dental occlusion is the primary objective, which ensures appropriate fracture reduction; however, rigid skeletal fixation also is a necessary adjunct. Both of these goals are interrelated objectives that cannot be compromised. Malocclusion after fracture reduction and fixation, in addition to adversely affecting function, will result in abnormal leverage against the fixation devices, resulting in disruption of the fixation.

Treatment Planning

Occlusion is used to determine the accuracy of the fracture reduction when comminution or gaps in the bone are present. Simpler fractures may be reconstructed anatomically. Performing anatomic reconstruction, without relying on occlusal evaluation should be performed with caution, as it is not unusual to have a malocclusion despite what appears to be a “perfect” reconstruction on the accessible outer (non-alveolar) bony surface.

Usually one side of the head/face is more severely injured; therefore, a common-sense approach is to repair the side with the simplest fractures first. The mandible should be repaired from caudal to rostral, with symphyseal separations secured as the last step.

Surgical Approaches

Although the fractured bone fragments often may be visualized within the mouth due to the extensive lacerations of the gingival that usually accompany these fractures, separate ventral mandibular approaches are the preferred surgical access. The ventral approach to each mandible facilitates exposure and bone fragment manipulation, including the ability to perform an accurate reduction and stabilization; furthermore, a route for ventral drainage can easily be established should it be required.

A separate lateral approach is required to expose the temporomandibular joint. The mandibular ramus dorsal to this joint need not be repaired.
References


Interfragmentary Wiring: Technique, Limitations and Clinical Application

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Interfragmentary Wiring: Technique, Limitations and Clinical Application

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Learner Objectives:

- Identify and describe mandibular fractures that are well-suited for repair employing interfragmentary wiring techniques
- Describe and employ interfragmentary wiring techniques for repair of mandibular fractures
- Provide specific recommendations regarding use of appropriate wire size for repair of mandibular fractures
- Discuss limitations and contraindications of interfragmentary wiring for repair of mandibular fractures
Background
Fractures of the mandible comprise about 3% of all fractures in dogs and about 15% of all fractures in cats. Mandibular symphyseal fracture/separation is the most common injury in cats and will be addressed as a separate topic during this course, whereas fractures of the mandibular shaft/body are most common in dogs and are frequently associated with vehicular trauma. As a result, concomitant injuries such as traumatic brain injury, other fractures or orthopedic injuries, and various soft tissue injuries are often present. Occasionally, jaw fractures are the result of trauma from kicks, swinging golf clubs or baseball bats, and gunshot wounds. Pathologic fractures associated with severe periodontal disease, especially in small dogs are not unusual. Caution should be exercised during extraction of teeth in small or toy breed dogs with periodontitis because iatrogenic fracture can easily occur. Because of limited soft tissue coverage of bone in the mandible and maxilla, even simple fractures are often open fractures and are considered to be contaminated or in some cases, especially with delays in treatment, infected. The primary goal of surgical repair of these fractures is early restoration of function. A secondary goal is preservation of cosmetic appearance. These notes should supplement the lecture on principles of interfragmentary wiring of mandibular fractures.

Mandibular Anatomy and Biomechanical Forces

![Diagram illustrating the bending moments in the mandible and distraction of the fracture during mastication. Arrows represent the direction of pull of the muscles during mastication. P=Pterygoideus, M=Masseter, T=Temporalis, and D=Digastricus.](image)
The predominant biomechanical forces acting on the mandible are bending forces and should be counteracted by any type of fixation used to repair mandibular fractures. Mastication causes the fracture to gap open along the alveolar border, which is considered the tension side of the bone (Fig 1). Since metallic implants are strongest in tension, they should ideally be placed on the tension (alveolar border) side of the bone; however, sole use of a tension band device such as an interdental wire will not counteract other forces such as shear and rotation. Other anatomical factors influencing placement of implants include the location of teeth, tooth roots, and the mandibular canal with its associated neurovascular structures. Interfragmentary wires should avoid these structures (Fig 2).

![Figure 2A: Canine mandible](image1)

![Figure 2B: Feline mandible](image2)

The goal of mandibular fracture repair is to restore normal occlusion and in simple fractures of the mandible, this typically relies upon accurate reduction of the fragments. Comminuted fractures and fractures with bone loss are difficult to align so dental occlusion is used to anatomically align the fracture. In these situations, it is helpful to place the endotracheal tube through a pharyngotomy incision. This removes the endotracheal tube from the oral cavity allowing intraoperative assessment of dental occlusion without interference from the tube. A standard ventral approach to the mandible provides optimal visualization of most mandibular shaft/body fractures. Fractures involving the angle of the mandible, the condyloid process and condyle, and the coronoid process/ramus are more challenging to expose due to increased soft tissue coverage. The mylohyoideus and genioglossus muscles are elevated from the medial aspect of the mandible and are retracted medially and the soft tissues/gingiva are elevated from the lateral aspect of the mandible. Generally speaking, the attachments of the digastricus muscle are left intact if possible since this is the only muscle that opens the jaw.

**Principles of Interfragmentary Wiring**

Interfragmentary wiring is used primarily for repair of simple fractures where perfect anatomical reduction is possible. Comminution, bone loss, and tooth loss reduce its effectiveness, at least as a sole means of fixation, because of the loss of the buttress effect. Placement of the wire should ideally be closer to the tension side of the fracture; however, placement is dictated by anatomy. Stainless steel orthopedic wire is most commonly used and it should be a gauge/diameter that is flexible enough to permit easy manipulation and placement without kinking or bending the wire during passage of the wire through the holes drilled in the bone. Larger gauge wire provides better stability but is more difficult to position and tighten. In addition, a larger gauge wire could overpower and tear out of the bone during tightening of the wire. In general, 20-22-gauge (0.6-0.8 mm) wire is used in most mandibular and maxillary interfragmentary wiring applications. In large dogs, 18-gauge (1.1 mm) wire can be used.
effectively where bone stock is more robust. Whenever possible, multiple wires should be used (2 interfragmentary wires or 1 interfragmentary wire combined with an interdental wire). Wires should be placed perpendicular to the fracture line whenever possible and holes for the wire should be drilled 5-10 mm away from the fracture line with the holes angled and converging towards the medial aspect of the mandible. The angled holes will facilitate placement of the wire on the medial side of the bone (Fig 3).

![Image](image1.png)

**Figure 3: Illustration depicting optimal interfragmentary wire placement.**

The roots of teeth and the mandibular canal should be avoided; however, it is acceptable to place wires in the furcation of multi-rooted teeth (Fig 4). The first wire should be placed as close as possible to the alveolar border and the second wire should be placed close to the ventral border while avoiding the mandibular canal.

![Image](image2.png)

**Figure 4: Illustration of 2 well-placed interfragmentary wires. Note that the wires have been placed perpendicular to the fracture line and wires avoid the tooth roots and mandibular canal.**

All wires should be preplaced and then sequentially tightened once the fracture has been reduced. Avoid acute bends or kinks in the wire because these will interfere with tightening the wire. By convention, wires are twisted in a clockwise direction to tighten them (i.e., “rightsie tightsie, leftsie loosie”). Another reason to twist wires in a clockwise direction, or to the right, is that the ratchet on the wire twisters are forced into apposition when twisting in this direction. Twisting in a counterclockwise direction tends to “spring” the ratchet open resulting in a loss of grip on the wire. Also pay attention to
how the wire is twisting—each arm of the wire should be twisting together rather than one wrapping around the other. With the wire, still loose but with a couple of twists, it is possible to take up the “slack” in the wire on the medial aspect of the bone by lifting the wire under the twist with a periosteal elevator (Fig 5). This will pull the wire up tightly against the medial aspect of the bone before the twist is completely tightened. The wire should be bent over during the last ½ twist and although only 1 and ½ twists are required for satisfactory security, I typically recommend cutting the wire leaving 2-3 full twists. Avoid leaving more twists as the twist can cause soft tissue irritation. With segmental fractures of the mandible, begin caudally and move cranially when placing interfragmentary wires.

![Figure 5: Illustration depicting removal of the "slack" in the wire on the medial aspect of the bone using a periosteal elevator.](image)

A variation on this technique for interfragmentary wiring is to place the wire in a cruciate or figure of eight pattern (Fig 6). This is particularly applicable to the most ventrally placed wire and is very effective for counteracting shear and rotation forces. The holes are drilled in the same manner as described above; however, the wire is crossed on the ventral aspect of the mandibular shaft. The other advantage is that the wire is always passed in a lateral to medial direction. When the wire is in a “simple interrupted” or loop configuration, the second pass of the wire through the bone must be done in a medial to lateral direction which can sometimes be challenging due to the soft tissues on the medial aspect of the mandible. Interfragmentary wiring can be combined with other fixation including bone plates and external fixateurs for more complicated or complex fractures. Wires (with the exception of interdental wires) are typically left in place unless they are causing a problem or are associated with an infection. Despite the open nature of most mandibular fractures, infections are not a common problem. Closure of the ventral approach to the mandible is routine. Any lacerations or incisions made in the oral mucosa/gingiva should be closed with an absorbable suture material. Antibiotics with a spectrum of activity effective against oral pathogens and with good tissue distribution in bone (e.g., clindamycin, amoxicillin clavulanate) are typically administered for 5-7 days after surgery. In cases of active infection, tissues should be sampled for bacterial at the time of surgery and appropriate antibiotic therapy should be based upon the results of antibiotic sensitivity testing.
Figure 6A: Immediate postoperative radiograph of a caudal mandibular fracture repaired using two interfragmentary wires. The ventral wire is placed in a figure of eight configuration.

Figure 6B: Intraoperative photo of an interfragmentary wire placed in a figure of eight configuration.
Symphyseal Fractures and Separation

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Symphyseal Fractures and Separation

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Learner Objectives:

• Recognize the differences in radiographic appearance of symphyseal separation and parasymphyseal fracture
• Analyze the rationale behind the differences in treatment of symphyseal separation and parasymphyseal fracture
• List various repair techniques for symphyseal separations and parasymphyseal fractures
Symphyseal Fractures and Separation

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**Symphyseal Separation vs. Parasymphyseal Fracture**
The treatment of choice for symphyseal fractures in humans is often placement of a single lag screw. This is not a desirable repair in companion animals for a variety of reasons. Unlike humans, dogs and cats have a fibrous union that separates the left and right mandibles. Common causes of trauma to this area include high-rise syndrome, motor vehicle trauma, and iatrogenic mandibular fracture during mandibular canine tooth extraction. When trauma causes a midline split of the mandibular symphysis, it is referred to as a symphyseal separation. Less commonly, trauma may result in a fracture of the bone lateral to the symphysis. This is referred to as a parasymphyseal fracture. Here’s what this looks like radiographically:

Figure 1:

<table>
<thead>
<tr>
<th>Symphyseal separation</th>
<th>Parasymphyseal fracture (through canine alveolus)</th>
</tr>
</thead>
</table>

The clinical relevance is this: the ultimate goal of repair of a symphyseal separation is to obtain a fibrous union. The ultimate goal of repair of a parasymphyseal fracture is to obtain a bony union. Therefore, placement of a single cerclage wire for three to four weeks will likely be sufficient for repair of a symphyseal separation. In contrast, a parasymphyseal fracture is best treated by rigid fixation. Back to the human lag screw analogy: in humans, a lag screw can be placed in the thick ventral cortex of the rostral mandible without damage to tooth roots or neurovascular structures. Lag screws are not an option in dogs and cats since there is no way to avoid tooth roots in the rostral mandible. For this same reason, external fixators are not a reasonable option in the rostral mandible of dogs and cats.
**Repair techniques**

*Symphyseal separation repair*

Prior to any repair technique, soft tissue wounds are debrided, lavaged and closed with absorbable sutures in a simple interrupted pattern. Cerclage is a simple technique that works well for symphyseal separations in dogs and cats. The traditional approach to this technique involves a ventral midline incision through the skin of the chin. An 18-gauge needle (larger gauge in dogs may be necessary) is inserted into the incision and courses between the lateral cortex and the soft tissues of the lateral lip distal to the canine teeth and rostral to the labial frenulum, keeping the needle as close to the bone as possible. A 22-gauge wire (larger gauge in dogs may be necessary) is passed through the needle. The needle is removed and reinserted into the ventral skin incision lateral to the opposite mandible in a similar fashion. The oral wire end is passed through the bevel of the needle and exits through the ventral skin incision. The needle is removed, and while the symphysis is stabilized in proper alignment, the wire ends are twisted in a pull-and-twist fashion until the lower jaw is stable. Excessive tightening of the wire may result in unnecessary cutting of the wire into the intraoral soft tissue. The twisted wire is trimmed and bent caudally, so that the skin covers it. A single cruciate nylon suture is placed in the skin. Alternatively, composite or acrylic may be attached to the exposed twisted wire ends to prevent injury from sharp wire ends. Three to four weeks later, the wire is removed by cutting the exposed wire loop in the mouth, bending up the cut wire ends, locating the twisted knot under the chin (the skin may need to be incised again), and pulling the wire ventrally. The mucosal and skin wounds are flushed with dilute chlorhexidine and left to heal by second intention.

An alternative technique for symphyseal cerclage was described in the Journal of Veterinary Dentistry in 2012. An 18-gauge needle is advanced as previously described into the oral cavity along the buccal aspect of mandible just rostral to the labial frenulum. The wire is threaded into the needle and the needle withdrawn. The needle is redirected along the buccal surface of the opposite mandible and, in this alternate technique, the needle is directed from intraorally to extraorally through the ventral chin incision. The orthopedic wire exiting the skin incision is threaded into the bevel tip and guided into the mouth by withdrawing the needle. Wire is twisted and tightened on the buccal surface of the canine tooth and the twisted ends are cut and bent back towards mucosa. A small bead of acrylic can be placed over the wire twists to prevent trauma from the sharp ends of the wire.

A figure-of-eight wire wrapped intraorally between the mandibular canine teeth may be considered in some cases but it is not generally recommended as it may cause linguoversion of the canines and may leave a gap in the symphysis ventrally if used as a sole form of fixation. Instead, placing a twisted wire between and securing it around the crowns of the mandibular canine teeth with composite will give additional stabilization and prevent lingual misalignment of the canines.

Leaving the wire in place for longer or overtightening bears the risk of bone and soft tissue necrosis and exposure of canine tooth roots.
Parasymphyseal fracture repair
A variety of options exist for repair of parasymphyseal fractures, and choices are made depending on the degree of displacement and concurrent trauma elsewhere in the mouth. As a general rule, these cases require more rigid fixation than would a symphyseal separation. Often this includes a combination of interdental wiring and composite splinting. Maxillomandibular fixation may be considered if concurrent caudal mandibular fractures are present. Figure 2 above shows how the patients in Figure 1 were approached. The patient with a symphyseal separation received a simple cerclage wire, whereas the patient with the parasymphyseal fracture had combination of modified Stout’s multiple loop interdental wiring and composite splint that incorporated the wire within the splint.
**Recommended Reading**


Interdental Wiring

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Interdental Wiring

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Learner Objectives:

- Describe how to place a Stout Multiple Loop interdental wire
- Describe how to place a Modified Risdon interdental wire
- Assess when to utilize a Stout Multiple Loop vs a Modified Risdon Technique
Interdental wiring is a noninvasive method of jaw fracture fixation that, when combined with composite splint placement, provides an excellent method for fixing mandibular body fractures where there are firmly rooted teeth that can be used as anchor points on each side of a fracture. The most common type of interdental wiring used is Stout’s multiple loop technique. Ideally, at least two teeth on each side of the fracture site are incorporated into the wire, which is placed in the interdental space between two teeth caudally, wrapped around the caudal anchor tooth, and loops are created by running the wire into and back through the interdental spaces using a 18 or 20 gauge needle passed beneath the gingiva but above the alveolar bone margin. Wire is passed through each loop and tightened rostrally along with each loop. This technique, along with acrylic splints, is one of the few that can take advantage of being applied to the tension surface of the mandible. Inclusion of at least two teeth on each side of the fracture is recommended to ensure stability of the repair. The Stout’s multiple loop technique utilizes a single wire weaved between teeth to create twisted loops. Once tightened, the twisted loops are gently and gradually bent into the interdental spaces and covered with composite.

Stout’s Multiple Loop Technique
Another commonly used technique is a modified Risdon technique, where wire is looped around teeth and twisted in areas of diastema or missing teeth. This twisted wire can be tacked down with addition wires looped around individual teeth, or the twisted wire can be tacked down with large gauge suture that bites into thicker gingiva of wide diastema between the teeth.


Composite Splints
Splints and interdental wiring work very well together, with the wire providing a similar effect to reinforcing bar within concrete. In the past, acrylic splints were fabricated with exothermic powder-liquid mixtures, which made extraoral fabrication necessary. Recently, a chemical cured composite used in human dentistry for temporary crowns (Maxi-Temp® or Protemp®) has become popular for fabrication of intraoral splints due to its ease of use and lack of exothermic reaction. After the soft tissue defects are sutured, the teeth are scaled and polished with pumice (not prophy paste!). The teeth are then dried and etched with 40% phosphoric acid, being careful to avoid contact with the soft tissues. After 40 seconds, the phosphoric acid is rinsed thoroughly and the teeth are air dried. At this point it is important to avoid getting moisture on the etched tooth surface. Composite is applied to cover all but the cusps of the teeth on each side of the fracture line, with more composite built up on the lingual surface for mandibular fractures or buccal surface for maxillary fractures to ensure the patient will be able to fully close its mouth in normal occlusion. The composite is shaped with a large bur to smooth any rough edges and minimize plaque retention. Even with best efforts, plaque and food accumulation under the splint will result in some degree of gingivitis. This can be minimized by vigilant home care, and will resolve once the splint is removed.
SELECTED REFERENCES


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Learner Objectives:

- Differentiate the various aspects of mandibular fractures that play a role in decision making associated with mandibular body fracture repair
- Describe the limitations of interdental wiring and composite splints
- Describe the limitations of various forms of rigid and flexible maxillomandibular fixation
INTRODUCTION
Maxillofacial injury results in the most obvious and disturbing consequences of trauma, but the patient must be assessed in its entirety to determine the best timing for repair of maxillofacial trauma. Patients with brain swelling, pulmonary contusions, airway obstruction or blood loss will benefit from stabilization prior to a long anesthetic procedure to repair maxillofacial trauma.

BALLISTICS
Gunshot wounds often result in severe trauma to the teeth, bones and soft tissues of the head. Initial presentation may manifest with severe blood loss from major arteries and veins that require immediate attention and ligation. More often, by the time the patient presents to the emergency room, the bleeding has largely subsided. It is important for clients to know that the true extent of tissue damage is not likely to be known for several days or weeks. Multiple surgeries may be necessary to deal with the consequences of high-energy trauma from a firearm or shotgun. In general, each and every bullet fragment does not need to be retrieved since dissection may be difficult and invasive. Bullet fragments that have been swallowed by the patient may result in increased serum lead levels and may need to be removed from the gastrointestinal tract if not passed. Also, long-term follow-up of teeth in the area is necessary to monitor for loss of tooth vitality.

HIGH-RISE SYNDROME
High-rise syndrome occurs most often in cats, but it occasionally occurs in dogs. The most commonly encountered findings include 1) symphyseal separation, 2) separation of left and right maxilla at the midline, sometimes with a split of soft tissue of the hard palate, 3) fractured maxillary canine teeth, 4) fractured palatal cusp of the maxillary fourth premolar, and 5) lingual slab fracture of the mandibular first molar. Symphyseal separation can be repaired with 20 to 24-gauge wire introduced with a needle lateral to each mandible just caudal to the crowns of the mandibular canine teeth. Midline palatal splits that cause a defect in the soft tissue over the hard palate may heal via granulation if narrow enough, but these defects should be apposed and sutured with absorbable simple interrupted sutures to minimize the likelihood of development of an oronasal fistula.

MANDIBULAR FRACTURES
Mandibular fractures are commonly a result of motor vehicle trauma, falling from a height, or interanimal aggression. In dogs, mandibular fractures often occur along the body of the mandible usually at the level of the canine tooth or mandibular first molar. In contrast, cats often fracture their mandibles in the caudal mandible near the ramus or condylar process with a concurrent separation of the symphysis. Factors that should be considered when deciding on a method of mandibular fracture repair include:
1) **Pathological vs. traumatic fracture** - patients sometimes will be presented with a jaw fracture in the absence of any history of trauma: be suspicious of a pathologic jaw fracture secondary to periodontal disease, especially in small breed dogs. These fractures that occur along a tooth root as a result of severe periodontal disease require either extraction or hemisection of the diseased tooth root to have a chance for the fracture to heal.

2) **Favorable vs. unfavorable fracture** - refers to the line of fracture. Fractures that extend obliquely from a dorsocranial to ventrocaudal direction are considered unfavorable due to the fact that three of the muscles of mastication (masseter, temporal, and pterygoideus) generate forces that act to separate the fractured segments.

3) **Location of fracture** - in areas where healthy teeth span the fracture site, these teeth may be used as anchor points using interdental wiring. Areas without teeth are more amenable to use of plates and screws since there are no concerns of iatrogenic damage to tooth roots created by screws.

4) **Degree of comminution** - the primary goal of fracture repair is to maintain normal occlusion while a bony union develops to achieve good long-term function without occlusion issues. Comminution may necessitate less conventional stabilization of methods in the form of maxillomandibular fixation or external fixators.

5) **Health of tissues/ length of time since fracture** - if much time has passed between the traumatic incident and presentation, exposure of fractured bone to the oral environment may affect healing, necessitating surgical debridement/removal of diseased bone.

**TYPES OF FIXATION**

Virtually every mandibular fracture benefits from some method of fixation. Types of fixation include: 1) tape muzzle, 2) maxillomandibular fixation, 3) wiring techniques 4) bis-acryl composite splint, 5) plates and screws, 6) external fixation.

**Tape Muzzles**

Indications for use of tape muzzles are important considerations for not only the veterinary dentist, but also for the general practitioner and emergency clinician. For the general practitioner and emergency clinician, tape muzzles represent a tool for temporary stabilization until more definitive stabilization can be accomplished. In some cases, however, tape muzzles may be used as the primary means of repair. For minimally displaced fractures in young, growing animals where other modes of stabilization may adversely affect growth or development, tape muzzles are often the treatment of choice. In cases where finances preclude surgical fixation of a mandibular fracture in the adult patient, tape muzzles can increase chances of a functional bony union when compared to no intervention. Muzzles may also be used as an adjunct to surgical fixation in patients where there is concern for how to restrict use of the healing mandible. Nylon muzzles of appropriate size may be used as a washable alternative to tape muzzles. Since tape muzzles do not fully immobilize fractured fragments, if bone healing occurs rather than a fibrous union or a nonunion, it will be via indirect healing and callus formation. A large callus may affect range of motion if the fracture is occurring in the caudal mandible. A variation of the tape muzzle that may be better tolerated by cats is a modified labial button technique that utilizes triangulated sutures that are run though the mucosa, skin and tension-relieving buttons and tied in a knot beneath the chin.
Maxillomandibular Fixation (MMF) via Intercanine Bonding

MMF is the small animal equivalent of “wiring the jaws shut”. The maxillary and mandibular canine teeth are etched and a composite material is placed to keep the upper and lower jaws in correct occlusion. The mouth should be stabilized in a slightly open position so that the patient can lap up water and slurry, but not too wide open where swallowing will be difficult. Cats may benefit from placement of an esophagostomy tube just prior to maxillomandibular fixation to ensure adequate caloric intake. Be aware that once the teeth are splinted together with composite, access to the back of the throat and airway is impossible without removal of the composite. Therefore, use this technique with caution in patients with concurrent airway disease, traumatic laryngeal swelling and/or vomiting. If composite bonding of the

Wiring Techniques

Wiring techniques can be divided into three general categories: cerclage, interosseous (interfragmentary), and interdental. Symphyseal wiring involves use of a cerclage wire advanced from an incision in the skin of the chin along the lateral border of each mandible just caudal to the crown of the canine tooth. The goal is to stabilize a separated symphysis without entrapping the soft tissue of the mandible within the wire. This may be accomplished by inserting a needle into the skin incision and walking it along the lateral border of the mandible. The needle should exit the oral mucosa just rostral to the labial frenulum. A wire of appropriate diameter based on patient size (24 gauge for cats) is passed through the needle and then the needle is removed. The needle is then advanced lateral to the opposite mandible and the wire is passed into the tip of the needle to allow for tightening under the chin. The wire is twisted until a balance between decreased symphyseal mobility and minimal soft tissue trauma is achieved. The twisted wire is bent to prevent the sharp edges of the twisted wire from snagging. A single skin suture is placed to cover the twisted wire. Since the symphysis is not a bony union, the wire should be left for no longer than 4 weeks to allow for fibrosis but to minimize complications of alveolar bone loss that invariably occurs with time. When the wire is removed, the wire is cut intraorally, and a small skin incision over the twisted portion of wire allows for removal. Interosseous wiring refers to the use of 20 to 26-gauge wire placed through holes drilled on both sides of a fracture line to allow for stabilization. Triangulation of the wire may be beneficial with two holes drilled in the caudal segment (one dorsal and one ventral) and one drilled in the rostral segment. Perhaps more desirable, two separate interosseous wires can be placed perpendicular to the fracture line but parallel to each other. Interdental wiring refers to the utilization of the teeth as anchors in which wire is weaved in the interdental spaces to allow for stabilization of a fracture.

Acrylic or Bis-Acryl Composite Splints

Splints and interdental wiring work very well together, with the wire providing a similar effect to reinforcing bar within concrete. In the past, acrylic splints were fabricated with exothermic powder-liquid mixtures, which made extraoral fabrication necessary. A chemical cured composite used in human dentistry for temporary crowns has become popular for fabrication of intraoral splints due to its ease of use and lack of exothermic reaction.

Limitations of interdental wire and composite splints are directly related to the health of the teeth on each side of the fracture line. Unfortunately, there is a pathologic component of periodontal disease with many mandibular fractures that may limit the use of teeth as anchor points. Sometimes all the teeth in the area of a mandibular fracture need to be removed, thus removing interdental wire from the equation.
In these cases, cerclage wires may be able to be incorporated into a composite splint in multiple locations along the mandibular body. This cerclage/composite technique works particularly well for oblique fractures of the mandibular body.

**SELECTED REFERENCES**


Application and Removal of Composite Splints / Incorporating Retaining Cerclage Wires

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Application and Removal of Composite Splints / Incorporating Retaining Cerclage Wires

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Learners Objectives:

- Recognize the steps necessary for successful placement and bonding of an intraoral composite splint
- Identify situations where mandibular cerclage wires may be beneficial for intraoral splint retention
- Identify basic materials used for the fabrication of an intraoral splint
The successful use of intraoral splints using provisional composite resin or acrylic has been repeatedly described in the literature for the successful treatment of maxillary and mandibular fractures. Both light cured and self-curing composites can be used. While the strength of the different materials has not been assessed in vivo, certain product materials may have increased strength over others. Popular materials include self-curing provisional crown and bridge material that has been reported to have a volume-dependent exothermic chemical reaction associated with curing. Recognizing that heat is produced becomes important when considering a potential risk for causing thermal pulpitis.

A primary benefit to using intraoral splints for fracture fixation is that it relies on noninvasive restoration of normal occlusion for fracture reduction. Composite splints are considered a semi-rigid form of fixation. By using semi-rigid fixation, micromotion is unavoidable and may contribute to a larger callous formation than if rigid internal fixation were applied. While micromotion may be associated with an increased risk of healing complications (fibrous union, nonunion, delayed union, etc) the micromotion may contribute to callous remodeling and promote bone healing in response to Wolff’s law. Intraoral composite splints are best suited for stable fractures, ideally with reasonable anatomic reduction. By using a closed reduction technique, there is no disruption of the fracture hematoma, no periosteal disruption around the fracture site, and a decreased risk of iatrogenic exposure to bacterial contamination at the fracture site.

Occlusal relationships between the mandibular and maxillary arcade should be considered when planning for intraoral splint placement. The anisognathic relationship between the mandible and maxilla necessitate that the splint be placed on the buccal surface of the maxillary arcade or the lingual surface of the mandibular arcade. By avoiding occlusal interference with teeth, concussive trauma or difficulty eating can be avoided.

Intraoral splints should be considered a “load sharing” form of fixation and best used in transverse or favorable fracture orientations in the mid-body or rostral mandible. Like other forms of fixation and stabilization, the intraoral splint will better withstand compression and tension forces if the distributed over a larger distance. Fabrication of a composite splint for fracture stabilization in the area of the mid-body or first molar region may reasonably extend from the ipsilateral canine tooth to the mandibular third molar. Fractures in the rostral half the mandible will likely require an intraoral splint that crosses midline. Intraoral splints may have limited application for patients with mixed juvenile and adult dentition.
Kern et al. demonstrated that fixation using a combination of interdental wiring and an intraoral splint had greater ultimate strength than either form of fixation used alone using 4-point bending. This was further supported when tested under load using cantilevered bending which more closely mimics force vectors created when chewing. When the M1 tooth is absent, combining interdental wiring and composite has been shown to be significantly stronger of noninvasive repair constructs. Paralleling the benefit of rebar reinforcing cement, the interdental wire may reinforce the composite and afford some additional rigidity before the composite fails under load. Whenever possible, reinforcing the intraoral splint with interdental wiring may be advisable since the fixation device may remain stable enough for healing despite wire breakage or splint fracture.

A combination of macromechanical and micromechanical retention is commonly applied to reduce the likelihood that the splint spontaneously dislodges. The divergent nature of the canine teeth serves as a macromechanical mechanism of retention when the splint incorporates these teeth. Since the crowns of the mandibular and maxillary canine teeth are divergent, there is natural retention reducing the likelihood that an intraoral device spanning both canine teeth will spontaneously slip off. Macromechanical retention is further improved by the presence of the interdental wiring. Loops and twists create an additional irregular surface for the composite to flow. Micromechanical retention may be desirable in some, but not all cases. Additional ‘staying’ power of the composite can be utilized through the use of tooth conditioning agents which provide a hybrid zone which permit the composite resin to form a chemical bond to the tooth structure. Use of tooth conditioning techniques and dental adhesives are necessary to create the “hybrid zone” (hydrophobic surface) necessary for chemical adhesion between the adhesive and composite. Specifics about tooth conditioning and application of dental adhesives can be found elsewhere in these proceedings.

Self-curing and light curing composites may be used for splint fabrication. Light curing composites may be cost prohibitive for use in dogs but may be sufficient for cats. Since light curing the composite is necessary and frequent, these procedures will take longer. Use of provisional crown and bridge self-curing composite is used more commonly. Layers of composite are applied to the tooth surfaces and unless the composite is expressed very slowly and constantly applied, it is reasonable to expect that the self-mixing tips will be replaced several times during splint fabrication.

Because the splint relies on micromechanical and macromechanical retention, circumstances exist where interdental wiring may not be possible or insufficient tooth surface area exists for reasonable chemical adhesion. In these situations, the use of mandibular cerclage wires can create the necessary macromechanical retention. Mandibular cerclage wires are placed prior to composite application and wire ends secured once most of the composite splint has been placed and cured. A second layer of composite is then placed over the splint in the oral cavity to ensure that sharp wire ends do not traumatize soft tissues.
Mandibular cerclage wires can be preplaced through the use of simple stab on incisions in the ventral mandible. A combination of blunt and sharp dissection to the ventral cortex of the mandible will allow the use of a 1 ½” needle to guide the orthopedic wire. The role of the cerclage wire is to secure the composite splint against alveolar bone. 24g to 20g wire can be used depending on the size of the patient. A corresponding 18 to 20g needle can be used to direct the wire. The needle should be directed through the stab incision alongside the lingual cortex of the mandible and penetrate sublingual mucosa as close the gingiva as possible. Orthopedic wire can be threaded through the needle with a free end existing the mouth. Beginning orally, the needle can then be directed through alveolar mucosa along the buccal cortex and the bevel tip directed through the ventral stab incision. Care should be taken to ensure the needle travels along bone and exits the stab incision in order to minimize trapping soft tissues once the wire is secured. The wire can be threaded into the bevel and needle withdrawn guiding the free end into the oral cavity. Preplacing cerclage wires with free ends in the oral cavity improve splint and wire removal since there will be no buried twists. After a majority of the splint has been formed, the wire twists ends are twisted to secure the splint against the alveolar crest or existing teeth. By placing the wire twists in the mouth, at the time of removal the cerclage wires simply need to be cut.

Use of intraoral splints can be challenging when trying to treat caudal mandibular fractures. Fractures involving the mandibular first molar tooth can become particularly challenging because of their common nature and considering the large surface area of the mandibular first molar, removal of the tooth can significantly reduce the micromechanical bonding potential of the composite. The low profile, and the tapered anatomic confirmation of the second and third molars are both features that limit the potential for enhanced macromechanical retention. To stabilize and seat the splint in this area, additional retentive techniques may be necessary such as mandibular cerclage wires or placement of transmucosal screws along the rostral surface of the alveolar ridge of the coronoid process.

Once the splint is placed, clients should be counseled that the animal should only eat liquefied or soft food for the duration of the fixation device. Hard toys, tug of war and rough housing should be prohibited. Recommended daily care of the splint should include irrigating the splint with water twice daily after eating and the use of a medicated oral rinse may help reduce mucositis and halitosis. Intraoral splints can be removed under general anesthesia after radiographic evidence of healing exists.

**Removal Techniques**

Removal of the composite can be challenging but should be straightforward. Scoring the composite using a diamond bur should create areas of weakness that a large dental elevator should be able to fatigue and fracture off segments. Wire cutters or a diamond bur can be used to cut the mandibular cerclage wires and the wires should be able to be pulled into the oral cavity with steady tension. Particular care should be taken when scoring the composite around tooth structure. Radiography may help determine the interproximal spaces if someone is unsure. The more areas the composite is scored, the
easier weaker it will be and easier to facilitate removal. Any tooth damage should be treated with a dental restoration. Immediately after removal of the splint, gingivitis/mucositis may be seen. While there should be no inherent discomfort associated with splint removal, a short course of anti-inflammatory medication or topical mucositis solution may benefit the patient. Small pieces of composite bonded to tooth structure can be ultrasonically or hand scaled to facilitate removal. Placement of acrylic or composite splints without conditioning the tooth structure first may result in much easier splint removal but lacks the micromechanical retentive qualities of the appliance.

**References:**


AOVET North America

Operative Treatment of Veterinary Craniomaxillofacial Trauma and Reconstruction

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Endodontic Implementation, Follow-Up, and Complications in the Trauma Patient

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Endodontic Implementation, Follow-Up, and Complications in the Trauma Patient

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Learner Objectives:

• Describe risks of teeth for developing endodontic disease in patients with oral and maxillofacial trauma
• Integrate measures to prevent iatrogenic injury to teeth at the time of treatment of jaw fractures
• Employ correct treatments for tooth wear, tooth fracture, tooth displacement injury, and teeth in jaw fracture lines
Endodontic Implementation, Follow-Up, and Complications in the Trauma Patient

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Introduction
Teeth often are injured as part of the oral and maxillofacial trauma, but dentoalveolar trauma can also occur as part of the treatment provided to repair maxillary and mandibular fractures. Jaw fracture repair from a veterinary dentist and oral surgeon’s point of view utilizes the following principles:

- Use non-invasive or minimally invasive techniques if possible
- Preserve structurally intact teeth in or near jaw fracture lines
- Avoid iatrogenic injury to other teeth, bone and soft tissue
- Restore proper occlusion and return to masticatory function
- Treat injured teeth and provide routine follow-up examinations

Teeth in or near Jaw Fracture Lines
Jaw fracture stabilization and postoperative occlusion are unfavorably influenced by extraction of structurally intact teeth associated with fracture lines. These teeth can contribute to proper alignment of fracture segments and provide anchorage for fracture repair devices. Extraction of a tooth in or near a jaw fracture line entails further trauma to and weakening of the bone and also presents technical difficulties when the bone fragments are highly mobile. The complication rate with regards to bone fracture healing is not necessarily lower following extraction of teeth located in fracture lines. However, if teeth with fracture lines extending along the periodontal ligament space towards the root apex are retained, they should be carefully monitored for evidence of periodontal or endodontic pathology, and appropriate treatment must be instituted as soon as either is recognized.

Injury to Teeth at the Time of Treatment
Minimally invasive techniques of jaw fracture repair are not entirely free of endodontic complications. Iatrogenic damage to the crowns of teeth (with or without pulp exposure) can occur during trimming or removal of an intraoral splint. Thus, it is recommended to leave the most coronal cusps of the teeth slightly exposed in order to know where teeth are located below the splint. Thermal damage to the pulp resulting in pulpitis or pulp necrosis can occur when heat is released during the polymerization of methyl methacrylate. Thus, splint materials that are not exothermic during the setting process
(such as bis-acryl composite) should preferably be used. Direct injury to the roots of teeth and their neurovascular supply can occur when placing wires, pins, and screws into the jaw bone. Good knowledge about the pertinent anatomy and careful planning of the surgery help to avoid iatrogenic root injury during implant placement.

**Restorations (Fillings)**

The outline of the defect preparation is made using a round or a tapered fissure bur. Macropenetration is created by using an inverted cone or pear-shaped bur, but the skilled veterinary dentist also uses hand instruments (dental chisels, hatchets and gingival margin trimmers) to shape and smooth the walls of the defect preparation. The prepared defect is rinsed with distilled water and dried. Amalgam is an alloy of silver and mercury with small amounts of other metals. Amalgam is strong and able to withstand years of wear. It does not bond to the tooth, and it therefore requires a mechanical interlock. Though amalgam is an easy material to work with, its metallic appearance and health concerns made other materials to become more attractive for restorative use.

Glass ionomer bonds chemically with hydroxyapatite of the tooth’s hard substances. Glass ionomer consists of aluminosilicate glass and polyacrylic acid. It has good resistance to abrasion but does not withstand compressive forces. Therefore, glass ionomer should not be used on occlusal tooth surfaces. Prior to placement of the material, the defect should be minimally prepared, and the dentin surface conditioned. Once the glass ionomer is placed, it should be protected with a layer of varnish to avoid either desiccation or hydration during curing. Once cured, the restoration can be shaped and smoothed.

Composite is a resin that contains ceramic filler particles. The polymerization reaction cures the material and can be either chemically activated (i.e., autocured) or initiated with a beam of visible blue light (450-470 nm). The size of the filler particles determines the restoration’s resistance to abrasion and smoothness after polishing. The smaller the filler particle, the lower is the resistance to abrasion but the smoother is the surface after polishing. Dentin is conditioned with polyacrylic acid for 20 seconds, and enamel is etched with phosphoric acid for 40 seconds. The acid is flushed away, and the tooth thoroughly rinsed with distilled water. The restorative defect is then dried with air from an air-water syringe. A layer of unfilled resin (“bonding material”) is placed and light-cured. Then one or two layers of composite are placed on top of the unfilled resin (concept of micromechanical retention) and light-cured, and the final restoration is shaped and smoothed. Composites are mixtures between composites and glass ionomers, combining the features of both restorative materials.

Extra retention of restorative materials to the tooth can be achieved by the use of pins and posts. However, the tooth itself does not become stronger with their use; instead, the tooth may in fact be weakened if tooth substance is removed for placement of devices that are designed to reinforce attachment of the restorative material.
**Vital Pulp Therapy**

Vital pulp therapy is primarily utilized for tooth fractures with ‘recent’ pulp exposure or after intentional crown reduction to preserve pulp vitality and increase the strength of the tooth by allowing continued dentin formation. Instruments and materials coming in contact with vital pulp must be sterile to prevent iatrogenic bacterial infection. Systemic antibiotics are recommended perioperatively.

The tooth to be treated and adjacent teeth are scaled and polished followed by rinsing with dilute chlorhexidine. Intentional crown reduction is accomplished by using a tapered cross-cut fissure bur in a high-speed handpiece with sterile lactated Ringer’s irrigation. Partial vital pulpectomy is performed using a round or pear-shaped bur in a high-speed handpiece with sterile lactated Ringer’s irrigation, removing 5-8 mm of coronal pulp. Hemostasis is achieved by gentle touching the pulp with the blunt end of multiple dry paper points. Direct pulp capping is performed with a 1-2 mm layer of calcium hydroxide powder (or mineral trioxide aggregate [MTA]) applied over the exposed pulp. This is followed by a 1-2 mm layer of calcium hydroxide cement (or other material), application of an intermediate filling material (e.g., glass ionomer) and a final restoration (e.g., composite). Dental radiographs are obtained in 6 months to confirm pulp vitality (presence or absence of a dentinal bridge under the previously placed calcium hydroxide, continued root development and apex closure).

Indirect pulp capping is indicated for near pulp exposure after trauma (very thin layer of dentin separating the pulp from the oral environment) or when a restorative preparation occurs within 1-2 mm of the pulp. A 1-2 mm layer of calcium hydroxide cement is placed prior to restoration, and the tooth is re-checked radiographically in 6 months.

**Apexification Procedure**

Apexification is the process of stimulating the formation of a closed apex when a necrotic pulp is present in an incompletely developed permanent tooth in young adult animals or in teeth of adult animals that have ‘open’ apices due to apical root resorption. The procedure is a type of temporary root canal therapy and involves cleaning, minimal shaping, and filling of the root canal with a calcium hydroxide paste, followed by temporary restoration of the coronal access opening (e.g., with a zinc oxide eugenol [ZOE] cement).

Radiographic reexamination is performed in 3 months. If apical closure is seen, the temporary restoration and calcium hydroxide paste are removed, and standard root canal therapy is performed. If apical closure is not evident, the root canal is refilled with fresh calcium hydroxide paste. The apexification procedure can be repeated in 3-month intervals until apical closure is achieved.

**Non-Surgical Root Canal Therapy**

If the pulp is exposed for longer periods of time or has become necrotic, non-surgical (standard or orthograde) root canal therapy is performed, consisting of accessing the pulp
cavity and debriding, shaping, disinfecting and obturating the root canal, followed by coronal access restoration. Perioperative dental radiography is essential.

Access holes are made at the mesial surface of canine tooth crowns about 2-3 mm coronal to the gingival margin. In two-rooted teeth, access holes are drilled into the crown over each root. In the maxillary fourth premolar tooth, the mesiobuccal and mesiopalatal roots can be accessed by creating one opening at the mesiobuccal crown surface approximately in the middle of an imaginary line drawn between the gingival margin and the tip of the main cusp (transcoronal approach). Debriding, shaping and disinfecting the root canal involves removal of all inflamed or necrotic pulp tissue and softened dentin to prepare it for obturation. The pulp chamber and coronal end of the root canal are carefully enlarged to facilitate access to and preparation of the apical portion of the root canal.

A small-diameter endodontic file is inserted into the root canal approximately 1 mm short of the apex to determine working length. Shaping of the root canal is performed by insertion of subsequently larger files to the predetermined working length. Use of EDTA paste alternated with sodium hypochlorite irrigation will help shape and disinfect the root canal. Each time file size is changed, a small-diameter file is inserted to remove any debris and dentinal filings (recapitulation) that may have been packed into the apical portion of the root canal by larger files used previously. Dentinal filings and debris are also removed by frequent irrigation with physiologic saline. Cleaning and shaping of the root canal are completed when clean white dentinal filings are seen and the next size file binds before reaching the working length. The root canal is recapitulated once more, disinfected with sodium hypochlorite, irrigated with physiologic saline, and then dried by successively inserting absorbent paper points into the canal with dressing forceps. The technique of cold lateral condensation is described below.

A dry master gutta-percha cone of the same size (or one size smaller) than the last file used during instrumentation is inserted into the root canal. A radiograph is obtained to confirm its placement to working length. Little resistance or tug-back should be felt when removing it. The zinc oxide eugenol (ZOE) sealer is mixed with a spatula on a glass slab and introduced into the root canal with a spiral filler attached to a reduction gear on a low-speed handpiece. The master cone is slowly inserted to working length, allowing excess ZOE to extrude out of the canal. A root canal spreader is inserted along the master cone to within 1-2 mm of the working length with apical pressure only, which will seat the master cone to the apical stop. The spreader is rotated on its axis several times, laterally condensing the malleable gutta-percha, and is then removed. Excess gutta-percha extruding out of the canal must be removed with a heated instrument below the access opening. An accessory gutta-percha cone (slightly smaller than the spreader) is placed in the space created by the spreader. Condensing with spreaders and introduction of accessory cones are repeated until it is impossible to insert an accessory cone farther than 5 mm into the root canal. A root canal plugger is then used to condense (compact) the gutta-percha apically. Residual sealer and gutta-percha must be removed from the coronal access area prior to restoration. A base of glass ionomer is placed over the gutta-
percha ends, followed by restoration of the access site. The tooth is re-checked radiographically in 6 months.

**Prosthodontic Crowns**
Metal crowns are primarily utilized to restore and protect fractured or weakened teeth of dogs that put their dentition at risk of trauma (e.g., police dogs, military dogs, prison dogs, etc.). Depending on how much of the natural crown of the tooth needs to be covered with a metal crown, we distinguish a full crown (the entire crown is covered by metal) or a partial crown (e.g., only the tip and three sides of the tooth are covered by metal).

After endodontic and initial restorative treatment of the tooth, a crown preparation is performed utilizing special burs that provide either feather, chamfer or shoulder margins. This will create space for a 1-mm thick metal crown to be seated onto the tooth. Once the crown margin preparation is performed, detailed impressions of the prepared tooth and full-mouth impressions (to make a stone model) with bite registration need to be obtained. All these materials are submitted to a dental laboratory with instructions how to make the metal crown. Once the metal crown has been fabricated (turn-around time is about 10-14 days), the patient is re-anesthetized and the metal crown cemented in position.

**Partial Tooth Resection**
Resection of a portion of a tooth can be a useful treatment for periodontally and/or endodontically involved carnassial teeth affected individually or in the line of a jaw fracture. Indications for partial resection of a tooth include inoperable root or crown-root fracture, external root resorption involving one root, impaired endodontic treatment of a particular root, advanced periodontitis affecting only one root, severe furcation involvement, and teeth in the line of a jaw fracture.

Root resection is the removal of a root with maintenance of the entire crown. Its indications are restricted to multi-rooted teeth where one or more roots cannot be saved. Hemisection is the splitting of a tooth into two separate portions. Trisection is the splitting of a (three-rooted) tooth into three separate portions. After sectioning of the tooth, all tooth portions are either retained or one or several tooth portions are extracted. If a tooth portion is extracted, this procedure differs from root resection in that it removes the corresponding crown of the resected root. Any retained crown-root segment must be treated endodontically. Traumatic hemisection refers to complete fracture through a furcation, resulting in severance of a fragment from the tooth. If crown-root segments with adequate bone support can be retained near jaw fracture sites, they may aid as anchorage structures for interdental wiring and provide surface areas for intraoral splints.
Surgical Root Canal Therapy (Apicoectomy and Retrograde Filling)
Non-surgical root canal therapy should have been performed first. The mesiopatalal root of the upper fourth premolar tooth is difficult to access, thus it is sectioned and extracted to salvage the remainder of the tooth. Access to the upper canine, upper fourth premolar and lower first molar teeth is made over the roots through an incision in the alveolar mucosa down to the bone. Access to the lower canine tooth is made through a ventral transcutaneous approach to the mandible.

The soft tissues are undermined with a periosteal elevator and reflected. Alveolectomy is performed with a round bur in a water-cooled high-speed handpiece. Apicoectomy is performed at a 10-45-degree angle with a tapered cross-cut fissure bur. About 3-6 mm of the apical portion of the root is resected, dependent on the size of the tooth. Inflamed or necrotic periapical tissues are removed with bone curettes, the apical opening into the root canal is prepared with an inverted cone bur, pear-shaped bur or hand instruments to provide a 2-3 mm deep restorative cavity. The surgical site is rinsed with sterile saline, to flush away debris, and then dried. Retrograde filling of the restorative cavity is performed with a zinc oxide eugenol cement, glass ionomer, or zinc-free amalgam. The tooth is re-checked radiographically in 6 months.

Tooth Displacement Injuries
Luxation refers to clinically or radiographically evident displacement of the tooth within its alveolus. Lateral or extrusive luxation occurs most commonly and is often associated with fracture of the alveolus. Intrusive luxation is a rare complication associated with trauma that forced a tooth with periodontal disease into the nasal cavity, resulting in chronic rhinitis and nasal discharge (this may sometimes be noted in retired racing dogs, e.g., Greyhounds). Surgical exposure through an intra-oral approach is required to remove the tooth. Avulsion refers to complete extrusive luxation and occurs after automobile accidents, falls from heights, fighting with other animals, or when a tooth gets caught in a fence. The teeth most commonly avulsed in dogs are the incisors and canine teeth.

Luxated and avulsed teeth require repositioning, stabilization, and endodontic therapy due to the likely loss of blood supply to the pulp. The success of reimplantation of an avulsed tooth is greatly influenced by the length of time that the tooth is out of the alveolar socket. Ideally, the avulsed tooth should be placed back into the socket immediately. If this is not possible, the tooth is placed in Hank’s Balanced Salt Solution (Save-A-Tooth). Systemic antibiotic therapy is instituted until the patient can be seen by the veterinary dentist. If an appropriate storage medium is not available, the tooth can also be placed in fresh milk, which maintains the vitality of periodontal ligament cells for 3-6 hours. Prior to reimplantation, the tooth is soaked in a doxycycline solution (1 mg in 10 ml lactated Ringer’s) for 5 minutes, and the alveolar socket is rinsed with the same solution (do not curette the alveolar socket or tooth root surface). The tooth is repositioned, and any gingival lacerations are sutured. A semi-rigid splint is applied, allowing physiologic movement. The pulp may be removed at that time, and the empty
pulp cavity is filled with calcium hydroxide paste, and the access site is restored with a temporary restorative material. Systemic antibiotic therapy is continued.

Endodontic therapy is performed 1 to 2 weeks later; the necrotic pulp is removed, the root canal filled with calcium hydroxide paste (or gutta percha if that step has already been undertaken), the access temporarily restored and the splint removed. Final root canal obturation with sealer and gutta-percha is performed in another 2 weeks. Long-term calcium hydroxide treatment is used when the injury occurred more than 2 weeks before initiation of endodontic treatment or if root resorption is evident on dental radiographs. The calcium hydroxide is changed every 3 months, and the root canal is obturated when a radiographically intact periodontal space and lamina dura can be appreciated around the root. Rigid splinting would prevent physiologic movement, leading to dentoalveolar ankylosis and root replacement resorption. If endodontic treatment fails, inflammatory root resorption can lead to rapid destruction of the tooth.

**Conclusion**
Structurally intact teeth can contribute to proper alignment of fracture segments and provide anchorage for jaw fracture repair devices. When teeth in or near jaw fracture lines are retained, follow-up is important so that treatment can be initiated if endodontic health is compromised. Injury to teeth (crowns and roots) should be avoided when treating oral and maxillofacial trauma patients.
Condylar Process / Coronoid Process Injury / Fractures

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Condylar Process / Coronoid Process Injury / Fractures

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Learner Objectives:

- Describe the basic principles of management of fractures of the condylar process
- Describe the basic principles of management of fractures of the coronoid process
- Associate the potential complications with the location, nature and management of the various types of fractures
Condylar Process / Coronoid Process Injury / Fractures

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Condylar Process Fractures
Temporomandibular joint fractures typically occur as a result of trauma and are often seen in combination with other maxillofacial injuries. We can classify TMJ fractures to be intra-articular and extra-articular. Moreover, the fracture can involve the condylar process and the mandibular head as a solitary lesion or cross the joint and involve the mandibular fossa as well. Furthermore, the fracture segments can be non-displaced or have displacement to various extents and may have fracture fragments within the joint space. Hence, it is crucial to have a full understanding of the fracture configuration prior to formulating a treatment plan. As in other TMJ disorders, fracture characterization should be made based on CT imaging. The goal of managing TMJ fractures is to restore mandibular symmetry, occlusion and function and to prevent long-term complications. In young dogs and cats as well as in most adult dogs (and based on the fracture configuration), non-surgical (i.e., conservative) therapy is the method of choice. In fact, there is excellent chance for fracture healing and regeneration of the damaged tissues as well as continuation of normal development in young dogs and cats with TMJ fractures. Maxillomandibular fixation (MMF) can be done in either one of 2 methods: (1) Rigid: a dental composite (i.e., temporization material) that ‘cement’ the mandibular and maxillary canine teeth in a closed-mouth position and allowing 10-20 mm of mouth opening; and (2) elastic: a placement of elastic device between the canine teeth and the patient have minimal guiding function and the jaws maintain minimal mobility.

In general, if there is a detectable malocclusion, then closed reduction and rigid therapy is recommended for a period of 7-14 days in young patients and 2-4 weeks in adults. Once the rigid MMF is removed, elastic therapy can be maintained for 2 additional weeks. Disadvantage of rigid therapy is delayed return to normal function, maintaining feeding tube, poor oral hygiene, difficulties in thermoregulation and potential aspiration. However, if the fracture is non-displaced and there is mild or no malocclusion, then elastic (functional) therapy is recommended for a period of 14 days. This will allow a more rapid return to normal function as compared to rigid therapy, allow the fracture area to receive more blood supply (due to the movement of the joint and muscles surrounding it) and decrease the chance of complications due to aspiration or thermoregulation issues. Open reduction is only recommended if there are fracture fragments in the joint space preventing opening or closing the mouth. Condylectomy is uncommonly indicated and should be reserved in case of complete destruction of the TMJ and for fragments that prevent the joint from regaining normal function.
Fractures of the Coronoid Process
Fracture of the mandibular coronoid process is uncommonly seen as a solitary lesion. Usually these fractures are seen in combination with other ramus or maxillofacial fractures. The coronoid process is well surrounded and protected by the temporal and masseter muscles and their vasculature. Mandibular coronoid fractures are treated conservatively, unless a severe displacement of the fractured coronoid process is observed or a functional mandibular impairment is encountered. If surgical intervention is indicated, coronoidectomy may be performed to prevent situations such as future pseudo-ankylosis or bone protrusion into the oral cavity. To date, studies validating the need (i.e., follow up studies) and the biomechanics of any surgical intervention such as open reduction and internal fixation are lacking.

References

Challenges and Treatment Approaches for the Edentulous Mandible

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Learner Objectives:

- Explain why fractures of the ramus and angle of the mandible are challenging to repair
- Demonstrate how the surgical approach to fractures involving this region of the mandible differs from that of approaches to the mandibular body or shaft
- Describe the ideal locations for implant placement and why
Background
Fractures involving the angle and ramus (coronoid process) of the mandible are challenging to repair due to at least two factors (Fig 1). Firstly, the surgical exposure of this region of the mandible is limited due to the overlying masseter muscle. It must be elevated from the lateral surface (masseteric fossa) of the ramus, and in most dogs, this is a very robust, well-developed muscle. A second factor that contributes to making these fractures difficult to repair is that the bone of the ramus, especially in the fossa, is quite thin limiting purchase of our orthopedic appliances in the bone.

Principles and Techniques of Repair
A caudal approach to the mandible is required to expose fractures in this area. The skin incision follows the caudoventral border of the mandible and curves dorsally towards the temporomandibular joint. The deep fascia over the masseter muscle is incised along the ventral aspect of the angle of the mandible taking care to avoid the dorsal and ventral buccal branches of the facial nerve. The masseter muscle is then sharply elevated from the masseteric fossa (Fig 2). Exposure is continued towards the alveolar border until the thick ridge of bone extending dorsocaudally from the last molar along the rostral border of the ramus is exposed. This area and
the caudoventral border of the angle of the mandible provide the best bone stock for application of the orthopedic appliance (Fig 3). The choice of implants used to repair the fracture will be determined by the configuration of the fracture and the availability of implants to the surgeon; however, interfragmentary wiring techniques, plating techniques, and external fixation are all applicable to repairing fractures in this location. The same surgical principles that guide repair of other mandibular fractures should be followed here. Implants should engage the thicker bone present along the rostral edge of the ramus just caudal to the last molar---fortunately this is the tension side of the fracture. If using interfragmentary wires or bone plates, a second implant should be applied to the thicker bone of the caudoventral border of the mandible. Bone plates can be contoured to extend either dorsally onto the condyloid process or caudally onto the angular process where screw purchase in the bone is usually quite good. External fixateur pins can also engage the bone in these areas. Even though the pins are non-planar, they can easily be connected using epoxy putty. The flexibility for pin placement makes this technique well suited for repair of fractures in this area (Figs 3 & 4).

![Figure 3: Illustrations depicting placement of orthopedic implants along the thicker rostral border of the ramus and the caudoventral border of the mandible. Plates can be contoured to extend either along the condyloid process or the angular process of the mandible.]

![Figure 4: Immediate postoperative radiograph of a simple fracture of the angle of the mandible repaired using interfragmentary wires. Note the placement of the wires along the tension side as well as the thicker caudoventral]
border of the mandible. 1 Day postoperative photo of a Dachshund with a fracture of the angle repaired using a free-form epoxy fixateur.

With highly comminuted, non-reconstructable fractures of the ramus/coronoid process, one may elect to manage these injuries more conservatively with a tape muzzle or interarcade bonding or wiring technique. Immobilization of the jaws should allow these fractures to heal by secondary bone healing, much the way a long bone fracture would heal with coaptation or external splinting. In some cases, coronoidectomy may be considered, especially with gunshot injuries where contamination or infection may be present.

Complications
Implant loosenings, delayed union, and infection are all potential complications. Loose implants, whether due to aseptic loosenings or infection, should be removed. An unusual but challenging complication of healing/healed coronoid fractures is trismus. This occurs when the coronoid process fuses with the zygomatic arch as a result of bone callus formation and fibrosis of the temporalis and masseter muscles. The zygoma may or may not have been fractured along with the coronoid but I believe that a concurrent fracture of the zygoma would increase the possibility of this complication occurring. Usually, these fractures are either managed conservatively (secondary bone healing) or are not initially treated and patients present due to an inability to open the mouth. I have seen this complication in both cats and dogs. CT scan of the head is usually necessary to visualize the problem and correction often involves resection of a portion of the zygoma and the coronoid process. Even after removing the bony interference, considerable force is usually needed to open the mouth due to associated fibrosis of the masticatory muscles.
Miniplating Principles

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Learner Objectives:

- Become familiar with the miniplate fixation system, both implants and instrumentation
- Describe the application of miniplates as it relates to the biomechanics
- Recognize both the indications and limitations of miniplate fixation
The objective of treatment presented for uncomplicated mandibular and maxillary fracture repair is to provide early rigid skeletal fixation with simultaneous restoration of dental occlusion; thus, achieving an immediate return to full function. Techniques and devices most often described for this purpose include: intraosseous wire, used alone or in combination with other skeletal fixation devices, and bone plates and screws.

Miniplates, although originally designed for use in human maxillofacial fracture repair, are ideally suited for comminuted mandibular and maxillary fractures in the dog and cat, and are especially useful for fractures located in the caudal mandible. However, because of their small size, they do not impart the degree of rigidity that is normally thought to be present with screw and plate fixation. Understanding this point, including that any implant is strongest in tension, dictates that this implant’s use be limited to the lines of tension stress in the mandible. Therefore, miniplates are applied in this area using the tension-band principle – identical to that employed with intraosseous wire fixation. The miniplates additionally provide the ability to obtain buttress support for fractures of the maxilla in comminuted fractures or those fractures that have a gap, due to either bone or tooth loss.

Miniplates are highly adaptable to the rapid changes in bony contour that are commonly encountered in both the mandible and the maxillofacial skeleton. Even in areas of thin bone, these implants can be secured without difficulty owing to the small screw size with a fine thread pitch. A thread pitch in bone at least equal to the bone thickness is sufficient to attain adequate bone purchase. In most areas of the canine and feline maxillofacial skeleton, bone thickness is ≥ 1 to 2 mm; screw thread pitch generally is > 0.5 mm and < 1.0 mm.
The miniplate in most maxillofacial systems is a titanium (Ti) implant of a low-profile plate design, generally 0.7 mm to 1.0 mm thick. Standard straight and curved plates are most common, but specialty plates (L, T, H, Y-shaped, and mesh plates) are also available. The screw hole is designed to accept the screw head to preserve the low-profile design after screw insertion into the plate. The low elasticity and high deformability of the Ti plates allows easy deformation in all planes, thus allowing exact adaptation to the contour of the bone in three dimensions. Additionally, the design conformation in the area of the screw holes within the plate and the connecting bridges between the screw holes are such that when bending, the deformation occurs primarily in the region of the connecting bridge without deformation of the screw holes; this feature is most important when locked screws are placed. Specialty plate benders are used to contour the plates to the shape of the bone. These bending pliers have a post design to ensure that screw-hole deformation does not occur. The posts are inserted into the screw holes of the plate and/or adjacent to the screw hole, which allows plate bending while simultaneously preventing deformation of the screw-holes. Most 2.0 mm miniplate systems use 2.0 mm screws with a 1.4 mm or 1.5 mm core. A 2.4 mm screw also is available as an “emergency” screw (with a 1.7 mm core diameter and a 1.0 mm thread pitch). Drill holes usually are made of the same diameter of the screw core to obtain a more secure fit between the screw-bone interface (as opposed to standard plate fixation, where screw holes generally are 0.1 mm larger than the screw core diameter). Because of the thin nature of the bone in most applications of the maxilla, precise drilling is essential. Drill speeds should be kept below 1000 rpm and must remain monoaxial, thus ensuring no subsequent adjacent bone necrosis or enlargement of the drill hole, respectively. Either of these factors will result in later screw loosening. Monoaxial drilling is crucial, as any change in the drilling angle will result in an oval hole in the bone; this problem is magnified with such small implants and thin bone. Enlarged screw holes are the primary reason for stripped screws – a common occurrence in the thin bone of the maxillofacial skeleton. For this reason, all maxillofacial implant sets include emergency screws of slightly increased size.

The stability of the fixation may be further improved by using a locking plate (e.g., 2.0-mm or 2.4-mm uniLOCK® mandibular reconstruction plate, Depuy Synthes® Vet), which will improve the overall purchase at the bone-plate interface. This may be especially useful when the plate is used in buttress or bridging fashion.
Maxillary fractures, especially in areas devoid of teeth are the preferred areas to use locking plates; however, they can be used adjacent to the maxillary or mandibular arcades if locking screw placement avoids the tooth roots. In areas where tooth root impingement may occur, the screw either needs to be omitted, or a standard screw that can be angled is placed.

Smaller veterinary miniplates are also presently manufactured (although not specifically designed for maxillofacial applications), e.g., the Advanced Locking Plate System (ALPS; Kyon, Boston, MA: USA). These plates are available in sufficiently small sizes (3.5, 4, 5, 6.5-mm) to utilize in the maxillofacial region. Specific bending pliers again are utilized in order to contour the plates both in-plane and out-of-plane three dimensionally – and preserve the plate hole configuration. Because of their point contact design, the vascular supply under the plate is better preserved and enhances the resistance to infection and improves healing.

Mandibular Fractures

Application of the fixation must consider the tension and compression surfaces of the bone. All fixation devices are strongest in tension (stresses parallel to the longitudinal axis of the implant); therefore, they should be placed along these lines of tensile stress, or on the tension surface of the bone. In cases of mandibular fractures, this location is along the alveolar border; however, the presence of the teeth can interfere with this most optimal biomechanical location. The use of miniplates allows these implants to be placed along this surface, as the small size of the screws allows their placement in between the teeth and/or tooth roots, identical to placement of intraosseous wire fixation. Either a 2nd miniplate, or a larger standard plate may be applied on the opposite (ventral) mandibular surface as a stabilization plate; again, identical to placement of intraosseous wire fixation. Such plate fixation is especially useful in comminuted fractures, or those with some bone loss, as they can function as buttress or bridging devices, which intraosseous wires cannot do. Use of a larger plate on the aboral surface (stabilization plate) further increases the stability of the fixation (and in some
instances, can be used alone, re: without a tension-band miniplate; however, this is a biomechanically inferior situation and must be used judiciously.

Plate fixation offers the advantages of inherent three-dimensional stability; furthermore, all bone fragments may be secured by neutralization or interfragmentary compression. Compression plates (DCP® or LC-DCP®, DePuy Synthes®) have been previously recommended as the ideal method of fixation of mandibular fractures. Reconstruction plates (DePuy Synthes®) also are recommended, and have the additional advantage of allowing three-dimensional bending/contouring, in comparison to DCP® plates, permitting the implant to be contoured more closely to the shape of the mandible due to the ability to perform an in-plane bend.

Accurate contouring and adequate screw purchase may be difficult with these larger implants in some areas of the mandible due to anatomic irregularities of the bone surface, especially at the junction of the mandible and ramus. Failure to carefully match the shape of the plate with the bone will result in a step at the fracture site when the plate is secured (and the screws tightened), resulting in secondary malocclusion. To some extent, the use of a locking implant overcomes this issue of inadequate contouring; however, failure to pay attention to these details – and carefully match plate/bone contours is overstated when using these small plates in the maxillofacial skeleton. Furthermore, with alveolar plate placement, orthogonal [locking] screws often cannot be placed due to the interference with the teeth, and thus standard screws are used to avoid the teeth – once again dictating that plate contours must be perfectly performed.

As noted above, the stability of the fixation may be further improved by using a larger locking plate (e.g., 2.0-mm of thicker dimensions or the 2.4-mm UniLOCK® mandibular reconstruction plate), which will improve the overall purchase at the bone-plate interface. This may be especially useful when the plate is used in buttress or bridging fashion. A locking miniplate is applied whenever prolonged healing is anticipated. The difference between a standard plate and a locking plate is the mechanism of load transfer between the plate and bone. In a locking plate, because the screws are
fixed within the hole of the plate, frictional forces between the plate and bone are not necessary to maintain construct stability.

Maxillary Fractures

Historically, the usual approach for many fractures in the maxillofacial region has been conservative management, i.e., limited or no fixation. This is most likely due to the difficulty of obtaining adequate stabilization of these multiple, thin bone fragments. Although interfragmentary wire fixation has previously been widely described as a method to stabilize maxillary fractures, simple interrupted wires cannot be used in many locations. Because the bone is very thin, overriding of the fracture fragments frequently occurs due to inadequate buttressing of these thin opposing bone fragments. Interfragmentary wire fixation often fails to provide the appropriate stability necessary for these fractures. Most standard plating systems are too large to be applied to the maxilla. The miniaturized plating systems are designed to achieve adequate screw fixation in these thin bone fragments. They also may be placed adjacent to the alveolar bone margin, similar to mandibular fracture fixation, and can provide accurate three-dimensional stability to each/all bone fragments they are secured to, and further act as buttress devices in their ability to support multiple comminuted bone fragments, or span gaps.

The midface has numerous sinuses, or air cavities, which are supported by either vertically or horizontally oriented struts of bone. These struts are referred to as “pillars” or “buttresses”, and have been illustrated in the human skull by architectural analyses. A similar anatomic construction of these trusses can be demonstrated in the dog, which similarly form the primary pillars of reinforced bone that provide the necessary bony support of the maxillofacial region. These buttresses provide the optimal place for plate fixation due to the thicker bone available.

Either a midline approach to the maxilla, or an intraoral approach can be utilized, or both. For securing the buttresses, locking plate fixation may be used, whereas plates placed along the alveolar border most likely need to be placed with standard screws so as to avoid impingement of the tooth roots (identical to the mandible). For more comminuted fractures involving the nasal, maxillary and frontal bones, a midline surgical approach usually is performed.

An intraoral approach also is often employed, reflecting the gingiva away from its attachments to the alveolar bone adjacent to the base of the teeth. The incision should be made approximately 2-mm from its attachment, thereby preserving an area for suture placement.
with subsequent soft tissue closure. The entire dental arcade, from the last molar to the incisors on both sides of the face can be exposed with a single incision in the gingiva. Miniplate location is immediately adjacent to the alveolar border. Plate location is kept below the infraorbital foramen of the maxilla laterally; similarly, the plate is kept below the nasal cartilages and applied directly to the incisive bone rostrally. Screw placement is performed so as to avoid the tooth roots, angling the screws in between the tooth roots of the same and adjacent teeth. Closure of the gingival mucosa is not impaired by the plate due to its low-profile design.

Regardless of the approach, occlusion is used to determine accuracy of the reduction. It is imperative that there is direct exposure of all fractures in order to ensure accurate anatomic realignment of the bone. Each/all bone fragments are reconstructed with the plate(s). If the bone fragments are too small to reconstruct, they are removed, and any gaps are spanned with a plate(s). Rigid buttress/bridging plate support is placed while ensuring passive and accurate contouring of the miniplate(s). The plates must be accurately and meticulously bent into the appropriate shape in order to passively fit the contours of the bone. The rationale of not performing such a meticulous job with locking constructs is overstated; the same dedication to accurate contouring must be used with both standard and locking plate fixation. If the plate is not accurately bent, the underlying bone will be pulled toward the plate, causing a corresponding shift at the occlusal level. A malocclusion, in addition to adversely affecting function, also may result in fixation failure as abnormal leverage is exerted against the fixation devices.
Supplemental Reading


Indications for Cancellous Graft Use and Collection Techniques

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Indications for Cancellous Graft Use and Collection Techniques

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Learner Objectives:

- Describe indications for use of cancellous bone to augment repair of mandibular fractures
- Provide locations for and describe the technique for harvesting cancellous bone in the dog and cat
- Summarize and describe the physiological mechanisms and benefits of cancellous bone grafting
- Describe alternate sources of bone graft
Indications for Cancellous Graft Use and Collection Techniques

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Background
The use of bone grafts in veterinary medicine is common and is indicated in any clinical situation requiring regeneration of bone or enhancement of bone healing. Specific conditions benefiting from employment of bone grafting techniques include bone loss due to trauma or tumor resection, treatment of non-union or delayed union fractures, augmentation of fresh fracture repair or repair of fractures in which pre-existing metabolic disease or age impede normal bone healing, arthrodesis, spinal fusion, and filling in defects associated with corrective osteotomy to name a few. A variety of bone grafts exist including autografts, allografts, xenografts, and allograft-based bone graft substitutes. Autografts are derived from the host and consists of autogenous cancellous bone, corticocancellous free grafts, and vascularized grafts. Bone allografts (cancellous and cortical) are obtained from donors of the same species, whereas xenografts are obtained from different species. Autogenous cancellous bone graft is still considered the “gold standard”, is the primary type of tissue used in veterinary medicine and, therefore, will be the focus of the remainder of this discussion.

Biology
Bone grafting techniques function to induce or enhance new bone formation by stimulating the natural processes of embryonic bone formation and secondary bone healing (callus formation). Cancellous bone graft contributes the biologic initiators of new bone formation including both mesenchymal stem cells as well as growth factors. New bone formation occurs through the processes of osteogenesis, osteoconduction, and osteoinduction.

Osteogenesis:
Osteogenesis refers to the ability of the graft to supply bone-forming cells to the process. Although most of the cells in an autogenuously derived free cancellous bone graft die, some cells in the mixture will survive and include cells ranging from fully differentiated osteoblasts to undifferentiated mesenchymal cells in the marrow component—the so-called osteoprogenitor cells. These cells can differentiate into any cell needed in the bone healing process. Also contributing to the osteogenic potential of the graft are growth factors that modulate and up-regulate the bone healing process (see osteoinduction below).

Osteoconduction:
Bone graft provides scaffolding upon which mesenchymal cells, osteoblasts, osteocytes, chondroblasts, and chondrocytes can migrate and proliferate—this is termed osteoconduction. Osteoconduction can occur on dead as well as live tissue and the load bearing properties of this scaffolding are determined by the nature of the graft.
Cancellous bone has poor load bearing characteristics when compared to cortical bone grafts.

**Osteoinduction:**
Bone healing requires an environment that is conducive to bone formation. Substances that possess the ability to induce bone formation when placed into a site where bone formation would otherwise not occur or be impaired are termed osteoinductive. Such substances attract mesenchymal stem cells and their progeny to the recipient site as well as promote proliferation and differentiation of these cells. Osteoinductive materials include demineralized bone matrix and a number of cytokines (growth factors), including transforming growth factor-\(\beta\) (TGF-\(\beta\)), fibroblast growth factor (FGF), insulin-like growth factors (IGF), platelet-derived growth factor (PDGF), and perhaps most importantly, bone morphogenic proteins (BMP). The most common and well-understood of these is BMP-2. BMP-2 is a potent initiator and stimulant of bone healing. Recombinant human BMP-2 has been used in veterinary medicine for treatment of segmental bone defects, non-unions, and spinal fusion.

**Collection Technique**
Autogenous cancellous bone graft takes advantage of all these aforementioned processes and substances to stimulate bone regeneration. Cancellous bone provides a scaffold for osteoconduction, live cells for osteogenesis, and a number of factors including BMP and other growth factors released from activated platelets including IGF, PDGF, and TGF-\(\beta\) for osteoinduction. Collection of cancellous bone is straight-forward and is well-tolerated in veterinary patients. The most common donor sites are the proximal humerus, the proximo-medial aspect of the tibia, and the iliac crest. Because the proximal humerus is readily accessible and is well-suited as a donor site for applications involving the oral cavity/mandible, the remainder of this discussion will describe collection of cancellous bone from this location. The hair is clipped from the area around the shoulder and brachium proximal to the elbow and a hanging leg prep is performed. The leg is surgically scrubbed and draped and a small skin incision is made over the lateral aspect of the greater tubercle just distal to the insertion of the supraspinatus tendon. Small Gelpi retractors are used to maintain the exposure, the periosteum is incised and elevated, and a Steinmann pin or drill bit is used to penetrate the lateral cortex of the humerus. A bone curette (3-0 to #2) is used to scoop the cancellous bone from the marrow cavity of the proximal humerus. Try to avoid enlarging the initial access hole in the cortex of the humerus to avoid creating a stress riser which could potentially result in fracture of the humerus. As the cancellous bone is retrieved, it can be stored in a 5 or 10 ml syringe (the plunger of the syringe is fully withdrawn and the graft, as it is collected, is placed in the “troughs” of the plunger). As graft fills the space between the barrel of the syringe and the plunger, the plunger is pushed in to protect the accumulated graft and keep it moist in the associated blood clot. Once collection is complete, the graft can then be transferred from the syringe to the recipient site. Graft collection should be performed just prior to its use since viable cell numbers decrease quickly. It is also advisable to use a clean set of instruments and to change gloves for collection of the graft to avoid contamination of the graft and the donor site. This is particularly true when the graft is used for reconstruction of defects resulting from tumor resection so as to avoid neoplastic
transplantation to the donor site. Closure of the donor site is quite simple. The deep subcutaneous tissues are routinely closed followed by the skin.
Introduction: Considerations for Buttressing Comminuted Fractures

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Introduction:  Considerations for Buttressing Comminuted Fractures

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Learner Objectives:

- Recognize that mechanical ramification of comminuted fractures
- Describe the use of locking reconstruction plates for bridging comminuted fractures
- Identify the causes for fixation failures and collateral damage
Introduction: Considerations for Buttressing Comminuted Fractures

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Introduction
Comminuted fractures of the mandible and maxillofacial bones pose a special challenge for the oral and maxillofacial surgeon. Specifically, restoring anatomical continuity and bone contour in the presence of instability, bony defects and bone displacement can be difficult. Untreated comminuted fractures may result in severe functional deficiencies and disfigurement.\textsuperscript{1-5} Comminuted fracture fixation need to have load-bearing fixation that is applied across the area of comminution.\textsuperscript{6} From that perspective, a comminuted fracture area can be mechanically regarded as a critical-sized defect as the bone fragments in the area of comminution do not provide buttressing to help and stabilize the fracture. Mandibular internal fixation by means of locking reconstruction plating and at least 3 locking screws on each side of the fracture is typically used for mandibular fixation for comminuted fractures or critical-sized defects.\textsuperscript{6,7}

Historically, open reduction of comminuted fractures and placement of internal fixation was considered inadequate as the theory was that open manipulation of the fractured area will strip blood supply to the bone fragments resulting in sequestration and infection.\textsuperscript{6} In addition, past experience with open reduction and the use of wire fixation of comminuted fractures was not good, resulting in infections, bone loss, non-union and associated morbidity.\textsuperscript{6,8,9} However, the current experience and knowledge demonstrate that comminuted fractures should be stabilized with a load-bearing titanium locking reconstruction plates or locking miniplates and locking screws as this approach provides a quick return to normal function and predictable bone healing.\textsuperscript{7}

Fixation failure is an important complication that can occur when bone quality is poor or mechanical load circumstances are unfavorable.\textsuperscript{10} Screw loosening, plate exposure through oral mucosal ulceration, and collateral damage to important adjacent anatomical structures are reported complications when a bone plate is positioned near the alveolar margins and sustains excessive stress.\textsuperscript{4,11-13} Fixation strength depends on a multitude of factors including plate positioning, configuration, and strength; screw geometry; and bone quality, biology, and load.\textsuperscript{10} Patient outcome is optimized by selection of a plate.
From a theoretical mechanical perspective, the tensile stresses are occurring at the alveolar margin and the compressive stresses are occurring on the ventral border of the mandible. In addition, the tension band principle takes advantage of the fact that anatomic reduction is strongest when fixation devices are loaded in tension and the placement of a small plate along the line of tensile stress (Champy lines) would impart sufficient strength to neutralize the applied functional forces after fixation. However, the tension band principle also relies on interfragmentary compression, which is not present in comminuted fractures or critical-size defects.

The locking plate system has a mechanical advantage over conventional plates as a locking plate possess a novel integration of a rigid interface between the plate and screws that enhances the stability of repaired bone constructs and allows more flexibility in plate position and application. The system has threads on the screws and plates that allow the screw to be locked into the plate, enhancing both primary and secondary stability. In addition, application and contouring of the plate is somewhat less critical than with conventional plates.

Figure 1 Comminuted fractures of the mandibles can be bridged with a single locking reconstruction plate placed just ventral to the roots of the teeth and dorsal to the mandibular canal.

The fractured mandible or a mandible with a critical-sized defect stabilized with locking reconstruction plate is significantly weaker than intact mandible. In addition, the authors are using a single locking reconstruction plate to stabilize comminuted fractures and critical-sized defects as there are no consistent biomechanical differences between a single plate fixation versus two-plate fixation. Finally, the use of an alveolar plate is likely to result in significant tooth root damage compared to the single plate fixation.
Reference List


Principles of Locking Plates: Implant Choices

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Principles of Locking Plates: Implant Choices

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Learner Objectives:

• Explain the mechanics of force transfer between conventional and locking plate fixation
• Recognize the effects of conventional vs. standard palates on the biology and mechanics of fracture fixation
• Become familiar with the different locking plate systems for maxillofacial fracture repair
Principles of Locking Plates: Implant Choices

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Conventional Plating. Because conventional plating relies on the friction generated between the plate and bone, accurate plate contouring is required to match the anatomic bone contour. In conventional plating, even if the bone fragments are correctly reduced prior to plate application, fracture dislocation will result if the plate does not exactly fit the bone as the screws are tightened a loss of reduction may then occur (loss of primary reduction). Furthermore, under an axial load postoperatively, if the shear forces are greater than the frictional forces between the plate and bone, loss of the fixation may occur due to toggling of the screws (loss of secondary reduction). Again, because the plate is compressed to the bone surface, the periosteum is compressed under the plate area, reducing or even interrupting blood supply to the bone. The result can be delayed bone healing due to temporary osteoporosis underneath the plate.

Finally, in cases with decreased bone quality, such as osteoporotic bone, screws cannot be tightened sufficiently to obtain the compression needed to support the plate to the bone. This may cause loosening of the screws and loss of stability, with ultimately a loss of the reduction. Despite these purported limitations, standard plating achieves good results in good quality bone, and in fractures traditionally fixed with lag screws to achieve direct bone healing.

Locked Plating. In this method, screws lock to the plate, forming a fixed-angle construct. Once the locking screws engage the plate, no further tightening is possible; therefore, the implant locks the bone segments in their relative positions regardless of the degree of reduction obtained. Contouring of the plate minimizes the gap between the plate and the bone; however, an exact fit is not necessary for implant stability. This feature is especially advantageous in minimally or less invasive plating techniques, or in areas with rapid changes of bone contour, because in these techniques exact contouring of the plate to the bone surface is difficult to attain. By locking the screws to the plate, the axial force is
transmitted over the length of the plate and the risk of a secondary loss of the intraoperative reduction is reduced as the load is more evenly shared with all of the screws and the plate. Finally, locking the screw into the plate does not generate additional compression; therefore, the periosteum will be protected and the blood supply to the bone preserved.

Such a fixed-angle construct provides advantages in osteopenic bone or multifragmentary fractures where traditional screw purchase may become compromised.

**Maintenance of reduction**

In conventional plating, even though the bone fragments are correctly reduced prior to plate application, primary loss of reduction will occur if the plate contouring does not exactly match the contours of the bone. With a locking plate construct, it is not necessary to have this degree of accuracy with plate contouring. Once the locking screws engage the plate, no further tightening is possible; therefore, the implant locks the bone segments into this position at that point. Certainly, contouring the plate minimizes the gap between the plate and the bone, but an exact fit is not necessary for implant stability.

It also is possible to have a secondary loss of reduction. Under an axial load with conventional plating, loss of reduction may occur with micromotion as the forces are concentrated on the screws, resulting in the screws backing out – thus losing the fixation (loss of frictional contact between the plate and bone). There is much greater stability present under a load when locking the screws to the plate. In this latter scenario, the axial force is transmitted over the entire length of the plate, thus reducing the possibility of loss of the fixation.

Currently, there are a number of manufacturers that have locking plate systems available for maxillofacial fixation; UniLOCK™ (Synthes® Vet), and ALPS (Kyon) are the systems discussed; however, other manufacturers may be utilized if the sizes are appropriate for the patient/bone in question.
UniLOCK™ (Synthes® Vet)

The 2.4 UniLOCK™ system is a locking reconstruction plate of a low-profile design. Standard 2.4-mm screws (1.8-mm drill bit) or locking screws, either 2.4-mm or 3.0-mm (1.8-mm or 2.4-mm drill bit, respectively) can be used with these plates. The locking screws have a special double-lead thread beneath the screw head that engages and locks into the threaded holes of the plate. Plates can be cut to the appropriate lengths (2 straight sizes are available: 12- & 20 holes), and because of the reconstruction plate configuration, may be contoured 3-dimensionally.

Some modifications to technique are required to place these implants. All bending must occur between the screw holes, or the shape of the hole may become altered, and the screw head will no longer fit within the hole. For the 2.4-mm reconstruction plate, this is difficult to attain; therefore, inserts are available that are temporarily screwed into the holes during the bending process. It also must be recognized that the screw must be centrally placed within the hole, requiring use of the appropriate threaded drill guide, which also screws into the plate during drilling. Finally, screw placement is perpendicular to the plate surface, i.e., there is no angling of the screw through the plate into the bone – unless a standard (non-locking) screw is used.

A 2.0 mm UniLOCK™ Mandible System also is available. In this system, 4 plate sizes are available: 1.0 mm thickness X 4.8 mm width (mini), 1.3 mm thickness X 5.0 mm width (intermediate), 1.5 mm thickness X 6.5 mm width (large), and 2.0 mm thickness X 6.5 mm width (extra-large). A number of different straight lengths are available depending on the plate size: 20-hole mini, 12-hole intermediate, 12- and 20-hole large and extra-large. These plates can be cut to the desired length. The plates will accommodate both standard and locking 2.0-mm screws. The locking screws have conical double-lead locking threads. The locking screws also have either a self-drilling or self-tapping tip. The screw heads also have the option of a cruciate recess or StarDrive™ recess for the screwdriver.
The locking screws must be centered within the plate hole using a threaded drill guide, and inserted perpendicular to the plate surface. This system also introduced a new type of recess in the head of the screw (StarDrive™); this configuration is designed to be self-retaining, reduce stripping of the screw head, and provide high torque screwdriver capacity.

Because of the plate design, it is possible to 3-dimensionally bend these plates and still protect the screw-hole; however, specially designed bending pliers are required. These bending pliers have a pin that inserts into the screw hole to help prevent deformation. They are designed for the mini- and intermediate plate sizes only. For the larger sizes, the combination bending pliers are used.

![Bending Pliers](image)

These plates are quite small and must be utilized with discretion, re: understanding their intended use for placement along the lines of tensile stress for mandibular and maxillary fixation. These plates have been used in veterinary surgery identically to their usage in humans for maxillofacial indication. However, the locking plate constructs may not be suitable for mandibular plate fixation in veterinary patients due to the inability to angle the screws in order to avoid the large tooth roots encountered. They are, however, ideal for maxillary fixation.

**ALPS (Kyon)**

The technical features of the “Advanced Locking Plate System” include: use of both standard and locking screws in all plate holes, and plate geometry to permit plate contouring in 3-dimensions (in-plane and out-of-plane bending) with specially designed instrumentation that allows bending (in either plane) while preserving the screw-holes such that the locking mechanism is not adversely impacted. The principle of application remains accurate contouring to the bone surface and compression of the plate to bone (point contact); however, due to the geometry of the plate, the contact area between the plate and bone is minimized. The purpose of this design is greater construct strength as plate/bone contact minimizes shear loads to the screws and improves torsional resistance to failure.

Plates are available in multiple sizes, which correspond to the width of the plate in mm: ALPS 3.5, 4, 5, 6.5, 8, 10, 11 (additional sizes also will be available in the near future). Screw sizes are relative to the plate size; ALPS 3.5 and 4 use 1.0 mm standard screws and 1.6 mm locking screws, ALPS 5 and 6.5 use 1.5 mm standard screws and 2.4 mm locking screws, ALPS 8 use 2.4 mm standard screws and 3.2 mm locking screws, and ALPS 10 and 11 use 2.7 mm standard screws and 4.0 mm locking screws.
In both of these locking screw designs, the threads on the heads of the screws have a Morse taper that matches the base of the plate hole so that the locking mechanism is a combination of thread/Morse taper. In addition, there is a DCU above this point of the screw-hole that can also be used with a standard screw; this allows a “hybrid” fixation using both types of screws.

Supplemental Reading


Mandibular Reconstruction:  Treatment Potentials and Limitations of Allografts and Vascular Autografts, Avascular (Free) Allografts

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Mandibular Reconstruction: Treatment Potentials and Limitations of Allografts and Vascular Autografts, Avascular (Free) Allografts

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Learner Objectives

- Describe perioperative considerations for mandibular reconstruction in dogs
- Explain advantages and disadvantages of bone graft substitutes utilized in avascular mandibular reconstruction
- State the basic principles of microsurgery for vascular mandibular reconstruction
Mandibular Reconstruction: Treatment Potentials and Limitations of Allografts and Vascular Autografts, Avascular (Free) Allografts

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Introduction
The loss of lower jaw bone may result from severe infection/inflammation (periodontitis, osteomyelitis), resective surgery (mandibulectomy), or trauma (such as gunshot injury). How much functional deficit is present depends on the location and extent of bone loss.

Loss of mandibular symphyseal integrity may result in two freely floating mandibles. Loss of the mandibular body (or a portion of it) or an entire mandible causes a drift of the lower jaw towards the site of the deficit, eventually allowing teeth to impinge onto the hard palate, opposing gingiva and teeth, and upper lip. The drift may also result in abnormal forces on the temporomandibular joints. While masticatory function should be our primary goal when considering quality of life issues, owners increasingly demand that esthetic changes are also addressed whenever possible.

Avascular Options
Bone grafting is a surgical procedure by which bone or a bone substitute is used to take place of a removed piece of bone or bony defect. Bone graft substitutes include allograft-based (demineralized allograft bone; used alone or in combination with other materials), factor-based (natural and recombinant growth factors; used alone or in combination with other materials), cell-based (mesenchymal stem cells; used to generate new tissue alone or seeded onto a support matrix), ceramic-based (calcium phosphate, calcium sulfate, and bioglass; used alone or in combination) and polymer-based materials (degradable and non-degradable polymers; used alone or in combination with other materials).

Mandibular reconstruction utilizing avascular options resulted in variable outcomes in the past. They included the use of autogenous bone (such as rib autografts) and bone graft substitutes. Bone morphogenetic proteins (BMP) have been used in reconstruction of mandibular body defects in experimental and client-owned dogs with good success. Commonly used bone graft substitutes in oral surgery include natural, real bone allografts, consisting of osteoinductive demineralized bone matrix (DBM) and osteoconductive cancellous bone chips, and synthetic, bioactive, osteoconductive ceramics, containing salts of calcium, sodium, silica and phosphorus ceramics.

Extraction of teeth rostral and caudal to the defect is often required prior to reconstruction to avoid placing screws through tooth roots. A transmylohoid or pharyngostomy intubation allows for assessment of the occlusion intraoperatively. Edges of the bone at each side of the defect should be freshened. While maintaining the desired occlusion of the rostral mandible based on canine and incisor relationships, a miniplate is placed along
the dorsolateral surface of the mandible spanning the defect. A 2.4 mm locking mandibular reconstruction plate is placed as a buttress stabilization plate along the ventrolateral surface of the mandible after being contoured to the shape of the mandible.

The critical size defect in dogs has been reported to be 4 cm, meaning defects smaller than that could eventually fill with new bone (assuming that the opposing bony edges in between the defect are adequately stabilized). A promising grafting material is an absorbable collagen sponge, containing hydroxyapatite/tricalcium phosphate (TCP) granules, which is cut to the size of the defect and soaked in BMP. This carrier is placed in the defect and the dissected musculature, subcutaneous tissue, and skin will be closed in standard fashion.

Autogenous bone can be harvested in many ways from areas local or distant to the oral surgical site, using rongeurs with narrow jaws to collect marginal and septal alveolar bone, manual trephines or trephine burs that retrieve larger blocks of cortical and cancellous bone, sharp periodontal or surgical curettes, back-action chisels or cortical bone collectors whose blades are scraped along an exposed bone surface, and bone cutting saws. The harvested autogenous bone is used as is or collected in a sterile dappen dish and reduced to chips as needed.

Guided tissue regeneration is a procedure utilizing an absorbable or non-absorbable barrier membrane to direct the growth of tissues of interest and prevent the ingrowth of undesired tissues into the defect. This technique has mostly been utilized for bone regeneration around teeth. However, a custom-fitted, absorbable barrier membrane could also be placed around the avascular graft that is situated in a segmental mandibular defect to prevent ingrowth of soft tissue into the grafted site. Absorbable membranes can be synthetic or natural.

**Vascular Options**

The role of vascularized autografts to repair mandibular defects is currently evaluated in laboratory animals and clinical patients. Microsurgery requires the use of an operating microscope. Anastomosis of small blood vessels (often having diameters of 1 mm or less) allows transfer of tissue from one part of the body to another and reattachment of severed body parts. Free tissue transfer involves the selection and isolation of donor tissue on a feeding artery and vein; this tissue is usually a composite of several tissue types (e.g., skin, muscle, fat, bone). The composite graft is transferred to the region on the patient requiring reconstruction. The vessels that supply the graft are anastomosed with microsurgical techniques to matching vessels (artery and vein) in the recipient bed.

The fibula is a common donor site for mandibular defect repair in humans. In dogs, the fibula appears less suitable as an autograft compared to the ulna or tibia. Microvascular ulnar and tibial autografts have been largely uninvestigated in veterinary mandibular reconstruction, despite the fact that they have been reported to be suitable free grafts for use in reconstructing bone defects in dogs. In cases where an ulnar autograft is used, the caudal interosseous artery and vein will be the donor vessels; a lag screw is needed to
secure the remaining distal ulna to the radius. The tibial autograft will be harvested together with its medial saphenous artery and vein; an external fixator needs to be placed at the donor site for 6 to 8 weeks immediately after harvesting the autograft.

The recipient vessels may include any suitably-sized arteries and veins in the proximity of the mandibular defect (e.g., inferior labial artery and vein, facial artery and vein, lingual artery and vein, etc.). Once vessel anastomosis is completed, and while maintaining the desired occlusion of the rostral mandible based on canine and incisor relationships, one or more miniplates may be used to secure the graft into position. Many of the surgical principles mentioned for avascular options also apply for vascular options. A 2.4 mm locking mandibular reconstruction plate is then placed as a buttress stabilization plate along the ventrolateral surface of the mandible after being contoured to the shape of the mandible and autograft.

**Conclusion**

Case selection for mandibular reconstruction is crucial. Avascular options using tricalcium phosphate and rhBMP-2 have been shown to be successful in a number of client-owned dog cases. Vascular options require particular operator skill, equipment, instruments and materials; they are complex, and more research is needed to justify their clinical use.
AOVET North America

Operative Treatment of Veterinary Craniomaxillofacial Trauma and Reconstruction

WEDNESDAY LECTURE ABSTRACTS
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Treatment Potentials for Managing Growth Disturbances Associated with Trauma
(Distraction Osteogenesis?)

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Midface Anatomy, Biomechanics and Buttressing (Human);
Panfacial Fractures, Management Strategies in Humans

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Panfacial fracture management challenges the surgeon to restore premorbid form and function. The high force injury that results in these fractures often causes significant injury to other organs that must be addressed before facial fracture management. These include the eye and CNS. Therefore, a comprehensive physical examination must be performed and the patient must be stabilized.

Treatment planning centers on the physical examination and careful imaging to document and characterize all injuries. By definition panfacial fractures involve 2 of the 3 segments of the craniofacial skeleton (mandible/ midface/ skull base). Deciding the surgical access required to expose, reduce, and fixate these fractures should be done based on the imaging.

Prior to fixation, all fractures should be exposed and reduced. This may be quite challenging due to the frequent comminution of fragments and missing or altered anatomical landmarks. Reference points from the more stable portions of the skeleton (skull base) and occlusion are extremely useful in confirming reduction.

Fixation must be performed to reestablish the vertical (condyles/midface), horizontal (infraglionic, infraorbital, palate, and zygoma), and projection dimensions (mandible and zygomatic arches) of the face. Extra attention to condylar fractures is necessary in these patients to reestablish the vertical dimensions of the face. The order of fixation depends upon surgeon preference but is more appropriately patient-based and often proceeds from stable to unstable and from known to unknown. Advocates of inside-out approaches and outside-in approaches are populated throughout the literature, but customizing the surgery to the patient’s specific defects likely gives the best results.

**Surgical Pearls:**
The sphenoid bone at the lateral orbit is a useful landmark for adequate reduction of the lateral midface before fixation. This is a stable bone that often allows for confirmation that the zygoma is not malrotated. A second pearl is to leave the Lefort I level fractures to the end. Often it is impossible to perfectly reduce all fractures in these comminuted
and extensive injuries. Accurate reduction of the mandibular unit and the craniofacial unit may still leave some discrepancy in the bone position. As long as the occlusion is reestablished, this minor bone displacement is best camouflaged at the LeFort 1 level.
Mandibular Reconstruction: Treatment Potentials and Limitations
Use of BMP

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Mandibular Reconstruction: Treatment Potentials and Limitations
Use of BMP

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Learner Objectives:

- Describe the principles of mandibular reconstruction using BMP
- Explain the limitations of mandibular reconstruction using BMP
- List the potential complications of mandibular reconstruction using BMP
We recommend a multidisciplinary approach for systemic stabilization after trauma. Specifically, oral and maxillofacial (OMF) trauma patients are evaluated by emergency and critical care, ophthalmology and neurology clinicians prior to anesthesia and surgical intervention. Diagnostic imaging is pursued once the animal is cleared for anesthesia. This is typically combined with surgical repair under the same anesthetic period.

**Dental Radiography**
Dental radiographs provide fine detail of the teeth, alveolar margin and trabecular bone. They are therefore indicated to assess concomitant dental disease and dental trauma, bone fracture lines and bone quality.

**Skull Radiography**
Skull radiographs are of limited diagnostic value in OMF trauma and rarely used. However, skull radiographs may be indicated to screen for temporomandibular joint (TMJ) involvement.

**Computed Tomography**
Computed tomography (CT) is becoming more readily available and affordable in veterinary medicine. It is indicated in OMF surgery in trauma cases to visualize the maxillofacial structures and TMJs. The use of CT with contrast medium is indicated for soft tissue conditions, such as masticatory muscle myositis. The CT scan should be acquired with a slice thickness as thin as possible.

**Cone-Beam Computer Tomography**
A recent advance in veterinary dental and maxillofacial imaging the cone-beam computed tomography (CBCT). With this imaging modality images are obtained with very high resolution. These can then be imported into special imaging software to evaluate the teeth and maxillofacial structures in great detail.

**Tridimensional Imaging and Printing**
Advanced mandibular and maxillofacial reconstruction surgery in veterinary medicine is becoming more common and receiving wider acceptance. However, these challenging cases require special preoperative planning due to the region's complex anatomy. The use of tridimensional (3D) imaging and, more recently, 3D printing as surgical planning modalities for mandibular and maxillofacial surgery in dogs and cats were recently introduced.
The use of 3D imaging following CT or CBCT is the standard of care at our institution and is performed by the attending surgeon. Several software programs are available for manipulation of DICOM files created by CT or CBCT for volume rendering and 3D imaging. This is routinely indicated for maxillofacial trauma cases as well as for oral tumor cases with bony involvement. It is also indicated for palatal defects, to compare the size and shape of the osseous defect with the soft tissue defect.

Having a 3D model provides the surgeon with the ability to perform precise preoperative planning and practice a virtual osteotomy and design a patient-specific implant preoperatively. The 3D printing of the affected skull overcomes this limitation and allows for a tangible understanding of the disorder and the precise surgical treatment. This may be further justified as precise presurgical planning may reduce the surgery time and allow for a reduction in overall surgical costs. They are also excellent tools for client and student education. Patients with complex mandibular and maxillofacial fractures may also benefit from 3D printing. The 3D printed skulls can be used for presurgical planning, plate selection and pre-bending of the plates, which saves on anesthetic time. For defect non-union mandibular fractures, the intact mandible can be mirrored for highly accurate pre-bending of the plate destined for the affected side.

Corrective ostectomies for ankylosis and pseudoankylosis of the temporomandibular joint can be very complex and not only involve the condylar process but also the coronoid process, zygomatic arch, and temporal bone. Precise preoperative planning and practicing a virtual osteotomy is possible with 3D printed models.

**References**


Midface Anatomy, Biomechanics and Buttressing (Dog);  
Maxillofacial Fractures, Management in Dogs

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Learner Objectives:

- Recognize the buttresses of the midface of the skull
- Describe the fixation methods to reconstruct fractures of the midface of the skull
- Identify the surgical philosophy/approach of midface fracture repair and the use of miniplates for these fractures
The maxillofacial skeleton must support and balance the identical forces applied by the mandible. The distribution of these forces, however, is very different from the mandible, as this area is subject to much less strain. The latter has the construction of an “outer facial frame” in humans, which acts as a link between the base of the skull and the occlusal surfaces. Support of the facial region is provided by a series of anatomic buttresses that distribute the masticatory forces to the head. These buttresses exist in the horizontal, vertical, and coronal planes. Three primary buttresses are present: defined anatomically as rostral (medial) nasomaxillary buttress, lateral zygomaticomaxillary buttress, and caudal pterygomaxillary buttress.

The caudal buttress is composed of the lacrimal, palatine, and pterygoid bones and is not readily accessible. The facial frame can be reconstructed utilizing just two of the three buttresses; thus, all attention is directed toward the medial and lateral buttresses. The caudal buttress is reduced indirectly as a result of primary stabilization of the other fractures of the maxillofacial skeleton and the skull. The vertical buttresses of the midface are the clinically most important with regard to the management of midface fractures to maintain the vertical dimension, or midface height. These buttresses are strong in resisting vertically directed stresses; however, they cannot withstand forces of similar magnitudes in the transverse plane. Although no similarly detailed biomechanical description of maxillary buttresses in the dog or cat has been performed, a similar anatomic arrangement to the human skull has been suggested and used successfully clinically in the dog.
The incisive bones are not part of the buttresses in the dog and cat and therefore may not need to be stabilized, as this area generally does not provide essential support to the skull; the nasal bones also may be fractured without disturbing the medial buttress. Fixation of the incisive or nasal bones still may be performed to provide support for the incisors or to re-establish the cosmetic appearance of the nasal area. Similarly, maxillary fractures may not require stabilization unless the buttresses are compromised. If the medial buttresses are compromised, malocclusion is likely, and loss of orbital support may occur. Similarly, if the lateral buttresses are compromised, the orbit is likely to be affected. Because of the anatomic configuration (a thin lamina that is reinforced by thicker areas of support) of the maxillofacial bone, plate fixation is ideally suited to reestablish the three-dimensional integrity; however, very small (mini) implants are necessary owing to the limited available space. The facial support provided by these buttresses reveals the design of a “truss” or “frame”, which is a triangle; in three dimensions, the basic truss is a tetrahedron, a three-sided pyramid that can resist distortion in any direction three-dimensionally.

These trusses can be similarly visualized in the skull as pillars of reinforced bone. In the dog, and presumably in the cat, the medial and caudal buttresses provide similar vertical support as in humans, although because of the configuration of the skull, these buttresses are better designed to withstand transverse forces as compared with those in humans. The lateral buttress appears to function primarily to withstand forces in the vertical plane; however, it also supports the other two buttresses, so as to better withstand increased shearing forces in the premolar/molar region in these species. The lateral buttress in the dog and cat thus may be the most clinically important, as it appears to more effectively neutralize forces in the transverse plane, despite lacking secondary lateral support adjacent to the orbit.
The latter is supported by the orbital ligament in the dog and cat, whereas this is bony support in humans and is part of the lateral buttress. The attachment of the maxillofacial skeleton to the base of the skull appears to have greater bony support in dogs and cats than in humans.

Historically, the usual approach for many fractures in the maxillofacial region has been conservative management, i.e., limited or no fixation. This is most likely due to the difficulty of obtaining adequate stabilization of these multiple, thin bone fragments. Although interfragmentary wire fixation has been widely described as a method to stabilize maxillary fractures, simple interrupted wires cannot be used in many locations. Because the bone is very thin, overriding of the fracture fragments frequently occurs due to inadequate buttressing of these thin opposing bone fragments. Interfragmentary wire fixation often fails to provide the appropriate stability necessary for these fractures. Most standard plating systems are too large to be applied to the maxilla. The miniaturized plating systems are designed to achieve adequate screw fixation in these thin bone fragments. They also may be placed adjacent to the alveolar bone margin and can provide accurate three-dimensional stability to each/all bone fragments they are secured to, and further act as buttress devices in their ability to support multiple comminuted bone fragments, or span gaps.

An intraoral approach is employed, reflecting the gingiva away from its attachments to the alveolar bone adjacent to the base of the teeth. The incision should be made approximately 2-mm from its attachment, thereby preserving an area for suture placement with subsequent soft tissue closure. The entire dental arcade, from the last molar to the incisors on both sides of the face can be exposed with a single incision in the gingiva. Miniplate location is immediately adjacent to the alveolar border. Plate location is kept below the infraorbital foramen of the maxilla laterally; similarly, the plate is kept below the nasal cartilages and applied directly to the incisive bone rostrally. Screw placement is performed so as to avoid the tooth roots, angling the screws in between the tooth roots of the same and adjacent teeth. Closure of the gingival mucosa is not impaired by the plate due to its low-profile design.

For more comminuted fractures involving the nasal, maxillary and frontal bones, a midline surgical approach also may be performed. Regardless of the approach, occlusion is used to determine accuracy of the reduction. The maxilla is reconstructed concentrating first on the lateral, and then medial, maxillary buttresses (in humans the medial buttress is addressed first in order to preserve midface height). Direct reconstruction of the posterior buttress is unnecessary as the medial buttresses will maintain correct position of the maxilla. It is imperative that there is direct exposure of all fractures in order to ensure accurate anatomic realignment of the bone. Each/all bone fragments are reconstructed with the plate(s). If the bone fragments are too small to reconstruct, they are removed, and any gaps are spanned.
with a plate(s). Rigid buttress/bridging plate support is placed while ensuring *passive and accurate* contouring of the miniplate(s). Once again, the plates *must* be accurately and meticulously bent into the appropriate shape in order to *passively* fit the contours of the bone. If the plate is not accurately bent, the underlying bone will be pulled toward the plate, causing a corresponding shift at the occlusal level. A malocclusion, in addition to adversely affecting function, also may result in fixation failure as abnormal leverage is exerted against the fixation devices. This is again true for *both* standard and locking plate fixation.
Supplemental Reading


Boudrieau RJ. Miniplate reconstruction of severely comminuted maxillary fractures in two dogs. *Vet Surg* 33:154-163, 2004


Management of TMJ Injuries:
Treatment Planning; Use of IMF Screws and TJM Surgical Approach

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Management of TMJ Injuries:
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Learner Objectives:

- Describe the fundamentals of TMJ Injuries and its ramifications
- Recognize the treatment modalities available to treat TMJ fractures
- Familiarize with the use of IMF screws and elastic chain “elastic therapy”
Management of TMJ Injuries:
Treatment Planning; Use of IMF Screws and TJM Surgical Approach

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Introduction

The temporomandibular joint (TMJ) is a synovial joint in which the condylar process of the mandible articulates with the mandibular fossa on the squamous portion of the temporal bone, and both the condylar process of the mandible and the mandibular fossa of the temporal bone are covered with a unique fibrocartilaginous layer. A fibrocartilaginous articular disk separates the TMJ cavity into dorsal and ventral compartments and fills the void between the condylar process and the mandibular fossa, which promotes the congruity of the joint. Importantly, the joint capsule attaches to the articular disk circumferentially, and a lateral ligament additionally strengthens the lateral aspect of the joint capsule. The sensory innervation of the temporomandibular joint is derived from the auriculotemporal and masseteric nerves of the mandibular branch of trigeminal nerve. From a proprioceptive perspective, the TMJ and its capsule have 4 receptors: Ruffini endings (static mechanoreceptors), Pacinian corpuscles (dynamic mechanoreceptors), Golgi tendon organs (static mechanoreceptors) and free nerve endings (pain receptors).

Temporomandibular Joint Fractures

Temporomandibular joint fractures typically occur as a result of trauma and are often seen in combination with other maxillofacial injuries. One can classify TMJ fractures to be intraarticular and extraarticular. Moreover, the fracture can involve the condylar process and the mandibular head as a solitary lesion or cross the joint and involve the mandibular fossa as well. Furthermore, the fracture segments can be non-displaced or have displacement to various extents and may have fracture fragments within the joint space. Hence, it is crucial to have a full understanding of the fracture configuration prior to formulating a treatment plan. As in other TMJ disorders, fracture characterization should be made based on CT imaging.

The goal of managing TMJ fractures is to restore mandibular symmetry, occlusion and function and to prevent long-term complications. In young dogs and cats as well as in most adult dogs (and based on the fracture
configuration), non-surgical (i.e., conservative) therapy is the method of choice. In fact, there is excellent chance for fracture healing and regeneration of the damaged tissues as well as continuation of normal development in young dogs and cats with TMJ fractures. Maxillomandibular fixation (MMF) can be done in either one of two methods:

a. **Rigid**: a dental composite (i.e., temporization material) that ‘cement’ the mandibular and maxillary teeth in a closed-mouth position and allowing 10-20 mm of mouth opening.

b. **Elastic**: a placement of elastic device between the canine teeth and the patient have minimal guiding function and the jaws maintain minimal mobility. The authors use IMF (intermaxillary) screws and elastic orthodontic chain (see specifics in lab instructions) to manage TMJ fractures in which there minimal to no malocclusion.

In general, if there is a detectable malocclusion, then closed reduction and rigid therapy is recommended for a period of 7-14 days in young patients and 2-4 weeks in adults. Once the rigid MMF is removed, elastic therapy can be maintained for 2 additional weeks.

Disadvantage of rigid therapy is delayed return to normal function, maintaining feeding tube, poor oral hygiene, difficulties in thermoregulation and potential aspiration.

However, if the fracture is non-displaced and there is mild or no malocclusion, then elastic (functional) therapy is recommended for a period of 14 days. This will allow a more rapid return to normal function as compared to rigid therapy, allow the fracture area to receive more blood supply (due to the movement of the joint and muscles surrounding it) and decrease the chance of complications due to aspiration or thermoregulation issues.

Open reduction is only recommended if there is/are fracture fragments in the joint space preventing opening or closing the mouth. Condylectomy is not recommended and should be reserved as an extreme measure in case of complete destruction of the TMJ and for fragments that prevent the joint from regaining normal function.
For severely displaced fractures of the mandibular fossa (squamous part of the temporal bone), reconstruction using miniplates may be indicated.

Figure 3: Severe displacement of the right condylar process in a dog. In this case a salvage procedure was performed and the fractured condylar process was removed.

Figure 4: Fixation of the mandibular fossa following a severe trauma. A 2mm titanium non-locking plate was used to reduce the mandibular fossa and resulted in healing of the bone.

**Surgical approach to the TMJ**

Surgical approach to the TMJ is seldom required. However, if the TMJ fracture is severely displaced or fracture fragments are present within the joint space, a lateral approach to the TMJ is used. The patient should be positioned in lateral recumbency with the neck extended and supported with a padded area. Once the zygomatic arch has been identified by digital palpation, the skin incision follows the ventral border of the zygomatic arch and crosses the TMJ caudally. The platysma muscle, directly under the skin, is incised on the same line. The origin of the masseter muscle is incised on the ventral border of the zygomatic arch and elevated using a periosteal elevator. The masseter muscle is retracted in rostroventral direction, avoiding nearby neurovascular structures. The TMJ is identified on the caudal aspect of the zygomatic arch. If possible, opening and closing the jaw may help to identify the joint. The joint capsule is incised craniolaterally and the condylar process partially visualized by manipulating the mandible. Closure is usually achieved in three layers. The periosteum and elevated
muscles constitute the first layer. The platysma and subcutaneous tissue are closed in a second layer, followed by the skin.

**Placement of IMF screws**

(Please see the section on Intermaxillary Fixation (IMF) Screws for more details)

**References**


IMF Screws; Implementation, Limitations and Strategies

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IMF Screws; Implementation, Limitations and Strategies

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Learner Objectives:
- Describe the fundamentals of the use of IMF screws
- Demonstrate the skills for placing IMF screws
IMF Screws; Implementation, Limitations and Strategies

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Background
Temporomandibular fractures can be classified as displaced or non-displaced fractures. Furthermore, TMJ fractures can be classified as intra- or extra-articular fractures. For the most part, intra-articular fractures are seen more commonly. For severely displaced fractures, a salvage procedure in a form of condylectomy or removal of the fractured condylar process may be done.

For minimally to moderately displaced fractures of the condylar process and the mandibular head as well as for minimally displaced fractures of the mandibular fossa, a conservative treatment can be made using IMF screws and an elastic orthodontic chain.

The benefits of using IMF screws and elastic chain (i.e., elastic therapy) are that it allows guiding the occlusion and permits guided masticatory function. This in turns allows good blood supply to the fracture area and to the supporting muscles of mastication. Importantly, when using elastic therapy, there is a gradual return to normal function and complications associated with rigid fixation (i.e., aspiration of food and water, inability to pant etc.) may be reduced.

IMF screws are self-drilling, and are fairly easy to use. They also shorten the operative and anesthesia time as compared to rigid fixation. Careful selection of the insertion site is required in order to avoid iatrogenic damage to the teeth roots or neurovascular structures. The authors make the decision on placement of IMF screws based on computed tomography and dental radiographs. Typically, the preferred location at the maxilla is just distal the canine tooth and mesial to the first maxillary first premolar tooth. For the mandible, placement of the IMF screw is also distal to the canine tooth and mesial to the first premolar tooth avoiding direct contact with the mandibular frenulum is possible. Complications associated with screw placement are associated with damage to dental or neurovascular structures and fracture of the screws due to excessive torque force at insertion.
Figure 1: An incision is made at the alveolar mucosa just distal to the maxillary or mandibular canine tooth and mesial to the maxillary or mandibular first premolar tooth.

Figure 2: Using a 1.5-mm drill bit and a drill sleeve, a small hole is created through the mucosa. Note that the company’s instruction indicate that pre-drilling is not necessary as the IMF screws are self-drilling. However, in the authors’ hands, having a small pre-drilled hole is much easier for accurate placement of the IMF screws.
Figure 3: a 2mm diameter, 8mm length IMF screw is mounted on a 1.5/2.0mm self-retaining screwdriver blade.

Figure 4: The IMF screw is inserted into the pre-drilled hole.
Figure 5: The IMF screw is in place. Note that the screw is approximately 3mm dorsal to the mucogingival junction.

Figure 6: Once the IMF screws are in place, an elastic orthodontic chain is placed to allow for a minimal mouth opening. Note that several chains can be placed depending on the desired mouth opening and stabilization. The number of chains are reduced over the healing period, guided by the clinician’s recommendations.
Figure 7: The use of IMF screws in a dog with bilateral TMJ and caudal mandibular fractures.

References

Reference List


