Growing dogs have a lot of orthopedic problems. These problems include developmental orthopedic diseases that start during growth (and often are not identified until later in life) and, less commonly, orthopedic injuries. This is counter intuitive to many owners (and clinicians) because people associate being young with being healthy, form an orthopedic point of view. The purpose of this lecture is to describe the most current medical practice to detect, assess, and manage orthopedic diseases and injuries in growing dogs. The lecture will include information on optimized detection of orthopedic problems based on owner discussion, observation, and palpation. Methods used to confirm the diagnosis will be presented. The conservative and surgical management of classic pediatric orthopedic problems will be described.

GROWTH
The musculoskeletal system of skeletally immature dogs undergoes profound transformations during growth. The duration of the growth phase is somewhat subjective because some growth plates in dogs do not close until several years of age. For example the pubic symphysis closes from caudal to cranial, starting at 9 to 21 months and finishing between 2 and 6 years of age, depending on the breed. From the perspective of longitudinal bone growth, the growth period lasts from birth to approximately 10 months of age. Orthopedic problems may arise as the result of impaired growth in dogs with genetic diseases, including chondrodysplasia, and other causes of impaired growth plate function (retained cartilaginous cores, hypertrophic osteodystrophy, etc.). Orthopedic problems may also arise from intentional dwarfisms (i.e., breeding dogs with short legs). Chondrodystrophic breeds include the Basset Hound, Dachshund, Shih Tzu, Pekingese, and many other breeds. Dwarfisms and chondrodystrophy have a clear impact on the shape of the forelimbs. They lead to elbow subluxation with secondary elbow osteoarthritis and to limb deformities. Dwarfisms have a less clear impact on pelvic limbs but they appear to be the cause of patellar luxation and, potentially, are linked to hip subluxation. Problems associated with bone growth become more visible during the most active growth period, between 3.5 and 5 months of age.

DEVELOPMENTAL ORTHOPEDIC DISEASES
Numerically, the majority of orthopedic problems in pups are the consequence of developmental orthopedic diseases. The most common orthopedic diseases are hip dysplasia, elbow dysplasia, and patellar luxation. Hip dysplasia is detectable as hip subluxation (by use of the Ortolani sign) or as hip laxity (by use of the Bardens sign) as early as three months of age. We can (should) confirm the presence of hip laxity (for example by using the PennHIP evaluation at 4 months of age—16 weeks of age). Elbow dysplasia or, more specifically the fragmentation of the medial coronoid process or the development of a cartilage lesion caused by osteochondritis dissecans of the medial aspect of the humeral condyle, is difficult to detect radiographically. These problems may be detected clinically as early as 3 months of age through the presence of a pain response to flexion or extension of the joint and the presence of joint effusion, seen as fluid collection on the caudolateral aspect of the joint in full extension. Elbow dysplasia may be confirmed by use of the DIMPLO view or by use of a CT scan. Patellar luxations may be detected at 4 months of age on palpation. Less severe patellar luxations are often diagnosed earlier than more severe patellar luxation. This may be the result of the fact that less severe (grade 1) luxations lead to visibly obvious clinical signs. Dogs will intermittently be non weight-bearing on their affected limbs, skipping steps while galloping or walking down steps. Dogs with severe (grade 3 or 4) luxations often after affected on both sides and often have more discreet signs. They keep their stifle joints in a flexed position (i.e., they lack stifle joint extension) and they shift weight forwards. Often, these signs are not recognized as clinically important until later in life. There are numerous other developmental orthopedic diseases but they are much less common. The most common of these uncommon diseases are osteochondritis dissecans (of the humeral head, trochlea of the talus, or femoral condyle) or an ununited anconeal process.
THE IMPORTANCE OF EARLY DIAGNOSIS & STRATEGIES TO ACHIEVE IT
Most developmental orthopedic diseases affect joints rather than bones. With time, irreversible changes occur in these joints: cartilage wears off, damage to the articular surface occurs and increases over time, the joint capsule thickens, compensatory orthopedic problems may develop, dogs may develop changes to their muscle mass, posture, gait, and weight distribution. Cartilage damage secondary to joint subluxation occurs within a few weeks and many changes are permanent. It is therefore critically important to diagnose problems in pups as early as possible. Since many problems fly under the radar of owners, it is the responsibility of the veterinary to screen pup for common orthopedic diseases. This screening should be performed on all dogs at 4 months of age. Owners should be informed of the importance of screening dogs for the presence of orthopedic problems before they detect gait changes or lameness. Discussing the importance and logistics (cost, duration, risks) of screening ahead of time increases compliance. The concept can be discussed at the time of initial set of vaccines, for example.

It is important to give the opportunity to owners to describe how the pup is doing at home. Being clumsy or doing funny things relating to locomotion should be a red flag because orthopedic problems in puppies often lead to gait changes interpreted as funny by owners. Lying down in an unusual body position may also be the consequence of an orthopedic problem, with a pup placing his limbs in a position to seek pain relief or alleviate subluxation.

Sedation (but not general anesthesia) should be used in active puppies. Our favorite sedation protocol includes a narcotic drug (hydromorphone, 0.05 mg/kg given intravenously) combined with a low dose of alpha-2 adrenergic agonist (dexmedetomidine, 1 to 3 µg/kg given intravenously). Alpha-2 adrenergic agonists should not be given to pups under 12 weeks of age because they lack the ability to increase cardiac contractility in response to the cardiovascular effects of the drug. Ideally, pups should be relaxed but slightly responsive during palpation. Palpation of pups include the assessment of the shape and symmetry of all joints and limb segments, flexion and extension of these joints, assessment of the presence of effusion in distal joints—elbows and stifle joints and below, the presence of crepitus or a pain response to palpation in all joints. Specific manipulations include the slow abduction of the hip joints to check for the popping sound made when the femoral head returns to its reduced (i.e., non-subluxated) position—the Ortolani sign. The stifle joint should also be palpated for cranial drawer, medial and lateral patellar luxations. A few millimeters of cranial drawer are within normal limits in pups but the end feel (the sensation perceived when the tibia is maximally cranially displaced) should be hard and not soft. A hard end feel indicated that the fibers of the cruciate ligament are taught. Also, there should be no effusion in the joint. As a general rule, effusion is a sign of a serious joint problem: most often the presence of a cartilage flap (in patients with osteochondritis dissecans), the avulsion of an intra-articular tendon (long digital extensor in the stifle joint, biceps brachii in the shoulder joint), an intraarticular physeal fracture, or juvenile septic arthritis.

ARTICULAR PROBLEMS
Most articular problems in growing dogs are the result of developmental orthopedic diseases: hip dysplasia, elbow dysplasia, patellar luxation, etc. Early and aggressive management could possibly be protective over a lifetime. Published information comparing early and late management is lacking. For the hip joint, early surgery (juvenile pubic symphysiodesis) appears promising for the lifelong management of hip subluxation. Less is known about the benefits of early removal of a fragmented medial coronoid process or early management of patellar luxation.

Joint injuries and luxations are relatively unusual in pups. Because ligaments mature more rapidly than long bones, trauma to long bones in pups is more likely to lead to a physseal fracture than a joint luxation. Some joint luxations are developmental. The most common developmental joint luxation is hip luxation secondary to excessive hip laxity. Other developmental joint luxations include the (medial) luxation of the shoulder joint seen in small dogs (Miniature Poodles). Elbow luxations or, more specifically, lateral luxations of the radial head may be seen in young dogs. Often, these dogs have a large, heavy body (English Bulldog). Beyond hip subluxation, other joint subluxations may be the results of developmental problems. In the tarsus, for example, we see hyperextension as the result of a cranial weight shift present in large dogs with hip pain. Their ankles become more and more extended over time and that excessive extension may interfere with their limb use. Other large dogs with angular deformities of their femurs have intertarsal rotational subluxations. Their foot basically freely rotate in relation to their ankle and it ends up externally rotated up to 90°. When these dogs walk, their stifles are pointing forward and their feet are pointing sideways. Puppies are at risk of avulsion fractures. Avulsions occur when excessive traction is placed on a bony structure by an extra-articular tendon (patellar tendon, triceps brachii tendon), an intra-articular tendon (see above), or a ligament (collateral or cruciate ligaments). Large avulsed fragments are reattached with Kirschner wires. A figure-of-eight wire is added if the puppy has only a small remaining growth potential.
PHYSEAL INJURIES
Physeal injuries are relatively common in dogs. They include fractures, partial closures, and complete closures. In one retrospective study, approximately one fifth of all fractures were physeal fractures. Physeal fractures most often require surgical stabilization because most of them involve the adjacent joint. The stabilization of physeal fracture is challenging because the fracture fragments are small and somewhat friable and because the reduction of these fractures should be precise, particularly if they involve the articular surface.

LONG BONE FRACTURES
Long bone fractures are relatively unusual in pups. They may be incomplete. The fracture of a single cortex is named a greenstick fracture. Greenstick fractures are sometimes treated conservatively, without surgery. They may lead to an angular deformity of the affected limb. Fractures without a large amount of instability, fragment displacement, or axial collapse may also be treated conservatively. Puppies heal rapidly but the healing process and shape of the healed bone are much less predictable after conservative management than after surgical management with a bone plate or an external skeletal fixation frame. Therefore, surgery is often a good management option that enhances the predictability of the outcome.

PHYSICAL REHABILITATION OF THE PEDIATRIC PATIENT
Physical rehabilitation has clear benefits in patients suffering from chronic disabilities and recovering from injuries. Physical rehabilitation aims at decreasing the pain associated with injuries and chronic inflammation, at maintaining or recovering the motion of abnormal joints, at limiting tissue changes associated with disuse (i.e., loss of muscle mass, bone mass, cartilage thickness and stiffness, ligament strength), and at protecting patients from further injury. The key philosophy of rehabilitation is to avoid limb immobilization and to create a safe environment for early and protected limb use.

The physical rehabilitation of pediatric patients presents unique challenges:
1. Growth changes the body over a period of weeks, making the progression of problems less predictable and making bandages and splints rapidly counterproductive.
2. Skeletally immature patients have distinct features and responses to injuries and immobilization that make them more prone to complications, these responses include:
   a. An exaggerated connective tissue response to injury. This response may lead to the invasion of limb compartments and muscles with rapidly maturing fibrous tissue and may lead to periarticular fibrosis.
   b. A rapid bone turnover leading to significant loss of bone mass after immobilization.
   c. A high likelihood of developing musculo-tendinous laxity after immobilization
   d. A relative fragility of the bone and of surgical repairs of pediatric fractures.
3. Juvenile and excitable personalities making the control of their activity and the delivery of nursing and rehabilitation care more challenging. Owners and therapist may have difficulties with manual therapy and therapeutic exercises because of the brief attention span and low obedience level of puppies.
4. A different relationship with owners because of the recent arrival of the puppy in a family. The absence of a long-term relationship may negatively impact the owners’ dedication and commitment to the recovery of their injured puppy.

PHYSICAL IMPAIRMENTS
Trauma is common in puppies. It may involve a fracture of a physis, of the shaft of a long bone, or the avulsion of a tendon or ligament. Fracture repair in puppies often occurs in the metaphyseal and epiphyseal region of long bones (i.e., near joints) and often consist of relatively weak fixation methods (i.e., Kirschner wires, bone screws, cerclage wires). Callus tends to be voluminous in puppies compared to adult, particularly when a fracture site is not fully stabilized. As mentioned above puppies are prone to contractures, including periarticular fibrosis, tendon laxity, and loss of bone mass after trauma and / or immobilization. Fortunately, puppies heal fast. These features make the recovery from injury an accelerated process compared to skeletally mature dogs. In puppies, problems rapidly improve or rapidly worsen. Recovery tends to be quick and complete and complications tend to be severe and irreversible. This raises the importance of a close oversight after injury and mandates a prompt and aggressive approach to early complications. As a general rule, it is very inadvisable to immobilize a limb in a puppy. The protected weight-bearing necessary to avoid mechanical failure of fixation may be achieved by crating puppies at all times when then are not under direct supervision, by avoiding interactions with other dogs except under direct supervision for socialization purposes, and by controlling the activity of puppies using an adapted chest harness.
Most orthopedic diseases develop during the rapid skeletal growth phase between 4 and 6 months of age. It is important to tackle these problems early to avoid secondary complications. For example, performing a juvenile pubic symphysiodesis at 16 weeks of age may successfully control hip dysplasia or severe patellar luxation may not have an impact of the overall limb development if operated between 4 and 5 months of age. As another example in an experimental model of elbow dysplasia with experimentally induced cessation of growth of the distal ulnar physis, it takes only two weeks the time before irreversible damage to the articular cartilage of the elbow joint occurs. Orthopedic screening should be performed in all pups with abnormal gait, lameness, or reluctance to play, or at 4 months of age in all high-risk patients. And changes in gait, posture, or muscle mass should be diagnosed promptly and managed aggressively. It is easier to maintain joint motion in the presence of an orthopedic problem that to recover it once lost. It is also easier to treat problem shortly after their occurrence, compared to later in life because the secondary changes happening in response to the original problems complicate management and may not be fully reversible.

![Figure 1](image1.png)  
**Figure 1.** Loss of joint motion in skeletally immature dogs (clockwise from top left). A young Beagle who had a bite wound developed a contracture of the quadriceps femoris. A young Miniature Poodle has lost stifle joint extension because of a grade 4 medial patellar luxation. A young Whippet is lacking range of motion in his digits. A young Doberman has a lack of carpal extension due to a lack of length of his flexor carpi ulnaris muscle.

Joint motion is critical to maintaining normal activities of daily living in dogs. Joint motion appears identical in skeletally immature dogs compared to mature dogs with few exceptions, including the cranio-caudal translation (cranial drawer) of the stifle joint present in some puppies. Decreased or increased joint motion is a very significant problem in skeletally immature dogs. Decreased joint motion may be the result of a muscular, tendinous, or capsular problem (Figure 1). The most critical problem is the contracture of a muscle because they occur rapidly and tend to be only partially reversible or irreversible. Muscle contracture is generally the invasion and replacement of muscle fibers by connective tissue. Contracted muscle bodies lose their elasticity and compliance. While a number of muscles of the forelimb and pelvic limb may contract, the most common contracture is the contraction of the quadriceps femoris muscle. A quadriceps contracture may develop in 7 to 10 days and is debilitating, most often leading to a non-functional pelvic limb that is ultimately amputated because of the fact that the leg functions as a peg and often develops damage to the dorsal aspect of the pes. Loss of joint motion may be due to abnormal muscle
growth in response to an abnormal posture. The most common example of this situation is the loss of stifle extension secondary to the tightness of semimembranosus and semitendinosus muscle in puppies with grade 4 medial patellar luxation (Figure 1). Loss of joint motion may also occur from the development of a tether (fibrous tissue bridge) of a tendon to the surrounding soft tissue. Tendons may be tethered to their retinaculum, to an adjacent bone or joint, or to adjacent fascia. A tethered tendon may result from a fracture, from tissue trauma (i.e., bite wound, abscess) or may be developmental. The most common tether appears to be a tether of the antebrachial flexor tendons leading to a lack of carpal extension. Unlike muscle contractures, muscles with tethered tendon maintain their elasticity and compliance. The tether may or may not be palpated, depending on its depth. Joint motion may be decreased because of a disparity between bone growth and the growth of musculoskeletal soft tissue. This is generally observed in large breed dogs with long legs (i.e., Pointers, Irish Setters) during their rapid growth phase.

Table. Common causes of abnormal joint motion in skeletally immature dogs

<table>
<thead>
<tr>
<th>Causes of loss of joint motion</th>
<th>Origin</th>
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</thead>
<tbody>
<tr>
<td>Muscle contracture</td>
<td>Femoral fracture, thigh injury, immobilization</td>
</tr>
<tr>
<td>Lack of muscle length</td>
<td>Grade 4 medial patellar luxation</td>
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<tr>
<td>Tendon tether</td>
<td>Articular trauma</td>
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</table>

<table>
<thead>
<tr>
<th>Causes of excessive joint motion</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developmental laxity</td>
<td>Breed predisposition (German Shepherd dogs)</td>
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<tr>
<td>Chronic weight shift</td>
<td>Hip or elbow dysplasia, limb deformities or denervation</td>
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</table>

Figure 2. Excessive joint motion in skeletally immature dogs (clockwise from top left). A young German Shepherd has lax carpi and to a lesser extent, tarsi. A young Rhodesian Ridgeback has flaccid superficial and deep digital flexor tendons after being treated with a splint for 17 days to protect a toe injury. A young Saint Bernard has hyperextended tarsi as a consequence of a forward weight shift that resulted from bilateral hip laxity and subluxation.

Loss of muscle tone may be present in skeletally immature dogs because of disuse, immobilization, or a neuromuscular disorder. It may or may not be associated with muscle atrophy. Puppies most often develop a loss of muscle tone because of joint immobilization (i.e., a veterinarian immobilizes a limb after a toe injury) or because of the lack of limb use resulting from a chronically painful situation (i.e., bite wound, abscess). Joint laxity and hyperextension may be present when an abnormal weight shift is present in response to the presence of pain (i.e., a puppy with bilateral hip pain shifts weight forwards and develops a hyper-extended stance in his talocrural joints) or because of the presence of a limb deformity or the presence of a non-functional contra-lateral limb (i.e., a puppy with a left brachial plexus avulsion develops a laxity of the shoulder joint on the opposite forelimb (Figure 2). Lax joints are predisposed to additional joint injury (i.e., collateral ligament rupture). Joint laxity is the root of hip dysplasia and possibly one of the causes of cranial cruciate ligament injuries.

TREATMENT METHODS
The priorities of physical rehabilitation in puppies are to maintain or restore normal joint motion and to avoid limb disuse. Unlike adult dogs that are treated based on their current physical limitations, puppies are treated based on their current and anticipated problems. The key challenge of puppy rehabilitation is to stabilize their original injuries in the least invasive and most stable manner and to keep them as active as possible to promote the motion of joint,
the use of muscles, and the weightbearing of limbs. This type of recovery plan requires close supervision by owners and therapists.

The primary rule of physical rehabilitation of skeletally immature dogs is to NEVER IMMOBILIZE IMMATURE LIMBS because immobilization leads to loss of joint motion, increased laxity of musculoskeletal soft tissues, and limb disuse. Protection from excessive activity in the period following an injury or surgery has to be achieved by restricting the activity of patients. This is achieved by placing patients in X-pens or airline carriers when they are not under direct owner or therapist supervision and to control them with a chest harness and short leash when they walking outdoors. In patients undergoing surgery, loss of joint motion occurs as a result of local edema and muscle tightness. It is not unusual to lack 30° of motion or more after the repair of an articular fracture. The therapist aims to gain 10° per week or more during the recovery process. Eliminating edema as early as possible is helpful to recover joint motion. This is achieved using ice, passive range of motion, finger massage, and light stretching. When the pain associated with injury or surgery subsides (usually after 3 to 5 days) joint motion is regained using stretching. Stretching may be achieved using manual therapy, through limb use and exercise, or using splints or braces. Limb use and therapeutic exercises are the most convenient and effective way to regain and maintain joint motion. In puppies who lost joint motion or who are predisposed to loss of joint motion, stretching should be performed often (hourly, in some instances) or continuously and range of motion should be assessed daily. Continuous stretch should be done cautiously because heavy bandages limit limb use and may heavy unintended consequences on the motion of adjacent joints. Patients with excessive joint motion should be treated by protecting them from the weight-bearing stresses, for example by encouraging aquatic exercises and limiting land-based exercises. Orthotic devices may be used during land-based activities but their use should be limited to avoid tendon laxity. Balancing nutrition by avoiding excessive energy or calcium intake, and decreasing food intake is also important.

Electrotherapeutic modalities (ice, heat, therapeutic ultrasound, neuromuscular electrical stimulation) are used sparingly in puppies. Ice is used in the early postoperative period for pain management and to limit and decrease edema. Therapy sessions are often shortened to accommodate for the short attention span of puppies. Therapeutic exercises are be adapted to skeletally immature dogs because they may not be used to be controlled and have limited endurance. Controlled indoor play is often a good therapeutic exercise for skeletally immature dogs because it promotes limb use through weight shifting.

In summary, the keys to the physical rehabilitation of skeletally immature patients are to closely monitor joint motion, to treat loss of motion immediately and aggressively, to protect lax joints from hyperextension, and to promote protected limb use.

REFERENCES