# การวิเคราะห์เปรียบเทียบการเคลื่อนไหวของขาหลังแบบ 2 มิติ ขณะวิ่งเหยาะบนสายพานลู่วิ่งในสุนัขพันธุ์ชิวาวาที่มีเข่าปกติ และที่มีสะบ้าเคลื่อนเข้าด้านในภายหลังการผ่าตัด

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# COMPARISON OF TWO DIMENSIONAL KINEMATIC ANALYSIS OF HIND LIMB DURING TROTTING ON TREADMILL IN CHIHUAHUAS WITH NORMAL AND MEDIAL PATELLAR LUXATION STIFLES AFTER SURGICAL CORRECTION

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กรรณิการ์ ฉายาทัพ : การวิเคราะห์เปรียบเทียบการเคลื่อนไหวของขาหลังแบบ 2 มิติขณะวิ่งเหยาะบนสายพานลู่วิ่งในสุนัขพันธุ์ชิวาวาที่มีเข่าปกติและที่มีสะบ้าเคลื่อนเข้าด้านในภายหลังการผ่าตัด (COMPARISON OF TWO DIMENSIONAL KINEMATIC ANALYSIS OF HIND LIMBDURING TROTTING ON TREADMILL IN CHIHUAHUAS WITH NORMAL AND MEDIAL PATELLAR LUXATION STIFLES AFTER SURGICAL CORRECTION) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. น.สพ. ดร. กัมปนาท สุนทรวิภาต, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ผศ. สพ.ญ. ดร. ชาลิกา หวังดี, 67 หน้า.

การศึกษานี้เปรียบเทียบการเคลื่อนไหวของข้อต่อขาหลังแบบ 2 มิติขณะวิ่งเหยาะบนสายพานลู่วิ่ง (ความเร็วลู่วิ่ง 1.11 เมตรต่อวินาที) ในสุนัขพันธุ์ชิวาวาที่มีเข่าปกติจำนวน 7 ตัว (14 ข้อเข่า) และที่มีสะบ้าเคลื่อนเข้าด้านในระดับ 3 จำนวน 10 ตัว (10 ข้อเข่า) และเปรียบเทียบการเคลื่อนไหวของข้อต่อขาหลังระหว่างสุนัขที่เข่าปกติ และสุนัขที่มีสะบ้าเคลื่อนเข้าด้านในก่อนการผ่าตัดและหลังการผ่าตัดในสัปดาห์ที่ 2, 4, 6 และ 8 โดยทำการศึกษาพิสัยการเคลื่อนไหวของข้อต่อ องศาการเหยียดข้อมากที่สุด องศาการงอข้อมากที่สุด และพิสัยการเคลื่อนไหวของข้อสะโพก ข้อเข่า และข้อเท้าหลัง จากการศึกษาพบว่า ข้อเข่าของสุนัขที่มีภาวะสะบ้าเคลื่อนเข้าทางด้านในมีพิสัยการเคลื่อนไหวข้อขณะย่างก้าว องศาการเหยียดข้อมากที่สุดและองศาการงอข้อเข่ามากที่สุดแตกต่างอย่างมีนัยสำคัญอย่างมีนัยสำคัญทางสถิติ ($p<0.001$), พิสัยการเคลื่อนไหวของข้อสะโพกและข้อเท้าหลังที่มากกว่าสุนัขในกลุ่มปกติอย่างมีนัยสำคัญทางสถิติ ($p<0.001$) และหลังจากทำการผ่าตัดแก้ไขสะบ้าเคลื่อนของสุนัขที่มีภาวะสะบ้าเคลื่อนเพื่อจัดแนวการวางตัวของกลุ่มกล้ามเนื้อ quadriceps ด้วยวิธี tibial tuberosity transposition, trochlear block recession, medial desmotomy ร่วมกับ lateral imbrication พบว่าพิสัยการเคลื่อนไหวของข้อเข่า ข้อเท้า และข้อสะโพกขณะย่างก้าวไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิตกับกลุ่มสุนัขปกติที่สัปดาห์ที่ 8 หลังการผ่าตัด ($p>0.05$) การศึกษานี้ทำให้ทราบว่า สุนัขที่มีภาวะสะบ้าเคลื่อนเข้าทางด้านในจะสูญเสียความสามารถในการเหยียดข้อเข่าซึ่งส่งผลต่อพิสัยการเคลื่อนไหวของเข้าเข่า และสุนัขมีการปรับตัวเพื่อยังคงความสามารถในการก้าวเดินโดยการงอข้อเข่ามากขึ้น และเพิ่มพิสัยการเคลื่อนไหวข้อสะโพกและข้อเท้าเพื่อชดเชยพิสัยการเคลื่อนไหวข้อเข่าที่สูญเสียไป นอกจากนี้การผ่าตัดแก้ไขสะบ้าเคลื่อนจะทำให้สุนัขกลับมามีการเคลื่อนไหวข้อต่อขาหลังได้ปกติที่สัปดาห์ที่ 8 หลังการผ่าตัด ความสำคัญทางคลินิกสามารถนำข้อมูลพิสัยการเคลื่อนไหวไปใช้ในการติดตามการรักษาได้ในทางคลินิก

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# # 5775301331 : MAJOR VETERINARY SURGERY
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KANNIKA CHAYATUP: COMPARISON OF TWO DIMENSIONAL KINEMATIC ANALYSIS OF HIND LIMBDURING TROTTING ON TREADMILL IN CHIHUAHUAS WITH NORMAL AND MEDIAL PATELLAR LUXATION STIFLES AFTER SURGICAL CORRECTION. ADVISOR: ASST. PROF. KUMPANART SOONTORNVIPART, D.V.M., Ph.D, D.T.B.V.S., CO-ADVISOR: ASST. PROF. CHALIKA WANGDEE, D.V.M., M.Sc., Ph.D, D.T.B.V.S., 67 pp.

The two dimensional kinematic motion analysis was carried out to characterize active range of motion (AROM), maximal extension angle (MEA) and maximal flexion angle (MFA) of stifle joint, hip joint and tarsal joints on sagittal plane in dogs during trotting on treadmill (velocity 1.11 m/s). Seven healthy Chihuahuas (n=14 normal stifles) and 10 Chihuahuas with grade III medial patellar luxation (MPL) undergoing surgical correction (n=10 MPL stifles) were studied. The parameters were comparing between normal group and MPL group undergone surgical correction at pre-operatively, 2, 4, 6 and 8 weeks post-operatively. The AROM, MEA and MFA of stifle joint in MPL group were significantly lower than normal group ($p<0.001$). The AROM of tarsal and hip joints in MPL group were significantly higher than in normal group ($p<0.001$). The surgical correction to realign the quadriceps mechanism was performed with the combined techniques of tibial tuberosity transposition, trochlear block recession, medial desmotomy and lateral imbrication. The AROM of hip joint, stifle and tarsal joints were not significant difference between MPL group and normal group at 8 week post-operatively ($p>0.05$). In conclusion, the MPL dog lost the performance of stifle extension. The stifle was more flexion and the degree of motion of the hip joint and tarsal joints were increased to compensate the trotting. Moreover, the AROM of hind limb joints could return to normal function at 8 week postoperatively.

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# CHAPTER 1
# INTRODUCTION

Medial patellar luxation is a common cause of abnormal gait encounter in small breed dogs. It is cause of intermittent lameness affecting the stifle joints in small breed dogs, especially Chihuahua, Pomeranian and Poodle (Alam et al., 2007; Nganvongpanit and Terdsak, 2011). Patella is a large sesamoid bone buried in quadriceps tendon which it primarily works as extensor mechanism of stifle joint. They are extremely crucial muscles aiding in important actions such as walking, running and jumping as well as they are important to stabilize the patella into the trochlear groove. These structures give a strong movement of the stifle joint which present as a term of joint angular motion or range of motion which it is descriped how much movement exist at a center of joint rotation. The motion loss of stifle joint is associated with gait abnormality which it is seen as a semiflexed posture during gait in dogs with medial patellar luxation.

Surgical correction for medial patellar luxation is dramatically required to realign the quadriceps apparatus, to stabilize a patella into the normal anatomical position, to restore the stifle extensor mechanism and to promote the normal range of motion. In general, the successful indicators of surgical correction are consisted of percentage of recurrence medial patellar luxation, recovery of their normal activities, qualitative lameness score, radiographic progression of osteoarthritis and weight bearing posture, which are subjective analysis (Gibbons et al., 2006; Linney et al., 2011; Segal et al., 2012; Wangdee et al., 2013; Stanke et al., 2014). However, it is still questionable whether improvement of these criteria can use as precisely indicators for stifle joint function. Although the recovering of weight bearing forces increases untill nearly normal after surgery, we cannot conclude that the quadriceps externsor mechanism of stifle joint also returns to normal motion. Lacking objective analysis to assess the outcome of surgical treatment is obscure in clinical evaluation and in research field. Kinetic gait analysis is a useful tool for objective analysis to evaluate the weight bearing properties in dogs with medial patellar luxation undergoing surgical correction (Wiputhanuphongs et al., 2015). Kinematic motion analysis may offer an objective method, and highly precise way to assess joint active range of motion (AROM) during gait. AROM presents full range of movement when a dog free to move on the joints (without assistance) using the adjacent muscles. In spite of cost, morbidity associated with medial patellar luxation, and its management, lacking study has focused on the joint angular motion of stifle joint during gait in this condition. This knowledge has a limitation for understanding about gait mechanism of dogs with medial patellar luxation and functional recovery of stifle joint after surgical correction.

The goals of this research were (1) to characterize AROM of stifle, hip and tarsal joints in clinically normal Chihuahuas (normal group), and to compare these parameters to those in Chihuahuas with grade III medial patellar luxation (MPL group) by using two-dimensional kinematic gait analysis during trotting over a treadmill (2) In addition, these parameters were used to compare between normal group and MPL group to assess the outcome of surgical correction at 2, 4, 6, 8 weeks post-operatively. We purposed to measure degree of maximal flexion joint angle (MFA), maximal extension joint angle (MEA) and AROM of the hip, the stifle and the tarsal joints. We hypothesized that (1) the degree of AROM of stifle joint, hip joint and tarsal joint would be different between normal group and MPL group (2) the degree of AROM of MPL group undergone surgical repair would return to normal motion during trotting within 8 weeks post-operatively. Clinical relevance, this kinematic motion analysis will allow detecting abnormal kinematic parameters that will be useful to evaluate surgical outcome by using objective measures in dogs after treatment.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Medial patellar luxation

Patellar luxation is recognized as a common stifle problem encountered in dogs. Small breed dogs are approximately 12 times greater risk of patellar luxation than large breed dogs (Priester, 1972). Dogs with patellar luxation have patella dislocated over trochlear ridge towards medial or lateral site of the stifle joint. Medial patellar luxation was more numerous (61%) than lateral patellar luxation (32%) or bidirectional patellar luxation (7%) in Dutch Kooiker dogs (Wangdee et al., 2014). Pomeranian, Terrier, Spaniel and Chihuahua are currently the top rank breeds for patellar luxation in the United States. The number of Chihuahuas with patellar luxation is greater than one-twentieth of the entire Chihuahua (OFA, 2016b). In Thailand, the prevalence of medial patellar luxation (approximately greater than 85% of entire cases) were more common than lateral patellar luxation in small-breed dogs (Wangdee et al., 2005; Nganvongpanit and Terdsak, 2011; Soontornvipart et al., 2013). The distribution of medial patellar luxation according to direction of luxation was bilateral more than unilateral (Campbell et al., 2010; Soontornvipart et al., 2013). Conversely, over 60% of 105 cases were primarily in unilateral medial patellar luxation (Nganvongpanit and Terdsak, 2011).

### 2.1.1 Etiology and pathogenesis

The patella is an important structure that enhances the mechanical efficiency of the quadriceps muscle and helps to maintain stifle stability (Clark et al., 2015). Dogs with medial patellar luxation have patella dislocated over trochlear ridge towards medial site of the stifle joint. Pathogenesis of patellar luxation has been extensively reviewed but it still remains unclear. It has been explained that the disease is a heritable, developmental abnormalities or traumatic in origin and it may cause minimal to severe gait abnormalities. Early diagnosis of bilateral patellar luxation in the predisposing breeds without accidental trauma supports the concept that patellar luxation may result from congenital anomaly or developmental malalignment of the quadriceps extensor mechanism. The trochlear groove is mostly shallow or absent in non–traumatic cases. Developmental patellar luxation is a consequence of complex bone conformation abnormalities affecting the overall alignment of the limb. It generally agrees that a defect in pelvic limb conformation is the underlying cause. An investigator suggested that the patella can dislocate because of two main reasons. One is the deviation of the tibial tuberosity (the insertion of the patellar tendon). The other is distal femur malalignment i.e. distal varus, valgus, internal or external femoral torsion (Petazzoni, 2011). However, a previous study showed if surgical correction for congenital medial patellar luxation was performed before 60 days of age, the bone deformities changes could be completely reversed with lateralization of the tibial tuberosity (Nagaoka et al., 1995). It indicates that the change in the distal femur is a consequence of the dislocation of the patella rather than a primary cause.

The medial deviation of action line of quadriceps mechanism results in abnormal forces on distal femoral physis and retards growth in medial side of hind limb. The typical deformities in medial patellar luxation are coxa vara (a decreased angle of inclination of the femoral neck), distal femoral varus and genu varum, shallowed trochlear groove, poorly developed or absent medial trochlear ridge with medial femoral condyle hypoplasia, medial torsion of tibial tuberosity associated with internal rotation of the tibia at the stifle joint, proximal tibial varus and internal torsion of the foot despite external torsion of the distal tibia (Kowaleski et al., 2012). Patellar luxation occasionally results from a traumatic injury causing sudden severe lameness of hind limb. Patellar luxation can result in the development of degenerative joint disease, pain, and lameness. Secondary osteoarthritis is a common disorder of medial patellar luxation (Roy et al., 1992).

**2.1.2** Diagnostic, classification and presenting signs

The diagnosis of patellar luxation is based on palpation. Nevertheless, gait evaluation must be taken place before performing the maneuver. Gait and posture evaluation are performed to determine the degree and character of lameness, to evaluate throughout morphologic abnormalities and to screen the bone deformities. The palpation is necessary to assess the position of patella during flex and extend stifle joint, to check the stability of the patella in medial and lateral directions, to assess whether patella can be reduced back to trochlear groove, to look for the degree of limb deformities, to observe the presenting sign of crepitus and to evaluate the joint range of motion. It is essential to characterize the grade of luxation and rule out concomitant cranial cruciate ligament disease or other pathologies that could cause hind limb lameness. Radiographic survey is useful to assess for concurrent problems such as Legg-Perthes disease and hip dysplasia. Moreover, it helps to evaluate the degree of degenerative changes presenting in the stifle joint and also to identify and qualify skeletal. Alternatively, computed tomography (CT) with 3D reconstruction of skeletal element is useful to qualify the deformities.
A luxated patella may be visible on radiographs however low grade of patellar luxation is intermittent and the patella may be reduced at the time of radiography. Clinical and pathologic finding are used to classify patellar luxation into four grades based on palpation of the affected stifle (Kowaleski et al., 2012; OFA, 2016a). In grade 1 patellar luxation, the stifle joint is almost normal and the animal often has no clinical signs. The patella luxated only when the joint is extended and digital pressure is applied. It can return to normal position but when pressure is released without manipulation of the limb. In grade 2 patellar luxation, a patella usually lies in normal position but it can be completely luxate. The manipulation of the hind limb causes the patella to regain its original position. Patient usually has some forms of gait disturbances. The limb is sometimes carried, although weight bearing routinely occurs with the stifle remaining slightly flexed. The hock is slightly abducted in medial patellar luxation case. If the condition is bilateral patellar luxation, the animal will shift weight to forelimbs. In grade 3 patellar luxation, the patella luxate most of the time, but it may be reduced

with the limb in the extended position or it permanently luxate but it can be manually repositioned. The stifle holds in a semi-flexed position. Flexion and extension of the joint might cause abduction and adduction of the hock, respectively. In grade 4 patellar luxation, the patella dislocates all the time and it cannot be reduced without surgical correction. The patient might have severe bony deformities. The animal often crouches, owing to the inability to extend the stifles fully, with its toes pointed inward. The owner often describes a skipping or hopping type of gait in which the animal skips one or more steps on the involved limb. This evidence is caused by the patella riding up and over the trochlear ridge and being trapped on the medial or lateral aspect of the joint.

### **2.1.3** Surgical correction of medial patellar luxation

Patellar luxation may be treated nonsurgically or surgically. Surgery is indicated in any aged patient exhibiting lameness. In general, surgical techniques used to correct patellar luxation varied depending upon the pre-surgical evaluation, intraoperative finding and revision by attending surgeon. The medial patellar luxation surgical correction is based on realignment of the quadriceps mechanism and stabilization of patella within the trochlear groove. The patella can be stabilized by deepening and widening the trochlear groove with a variety of trochleoplasty techniques, medial retinacular desmotomy and lateral imbrication. Extensor realignment can be performed by tibial tuberosity transposition, antirotation suture of the tibia, distal femoral ostotomy to correct the femoral varus and proximal tibial ostotomy (Piermattei et al., 2006). The trochlear groove correction is usually enrolled first, the extensor mechanism is realigned second, and parapatellar soft tissue balance is the last step. If the osteotomy is required, it should be performed prior to trochleoplasty techniques (Kowaleski et al., 2012). Several modified techniques for MPL surgical correction have been established such as the latero-distal transposition of the tibial crest and kite shield-shaped wedge recession trochleoplasty (Segal et al., 2012; Katayama et al., 2016). However, there is still relatively small number of cases that underwent these modified surgical procedures.

The goal of surgical correction of medial patellar luxation is to realign the quadriceps apparatus and the patella into normal physical and anatomical positions to restore the extensor mechanism and to return the normal stifle joint movement (Denny and Butterworth, 2008). Post-operative outcomes have been considered mostly in terms of percentage of patellar reluxation, developmental of osteoarthritis, stifle joint function by evaluating range of motion using goniometer and qualitative lameness score. Major complications are the patellar reluxation and implant failure requiring additional surgery. Minor complications are wound related problems such as discomfort and seroma formations, swollen straight patellar tendon, and proximal displacement of tibial tuberosity (Gibbons et al., 2006; Linney et al., 2011; Segal et al., 2012; Wangdee et al., 2013; Stanke et al., 2014). Motion loss is devastating complication of stifle surgery in human (Millett et al., 2001). In dogs, loss of extension or flexion ≥ 10 degree was responsible for higher clinical lameness scores and osteoarthritis in the cranial femorotibial joint led to extension loss (Jandi and Schulman, 2007). Immature dogs seem more likely to lose joint motion after surgery than mature dogs (Marcellin-Little et al., 2015). Lossing of normal range of motion for the joint after surgery might be caused by capsular stiffness and periarticular scar formation. The thickening fibrous joint capsule and adhesion of normally mobile tissue planes result in limiting the ability of tissue to glide over one another. Musculotendinous tissue may be shortened as a result of spasm (Millis and Levine, 2014b).

**2.2** Anatomy and biomechanics of stifle joint

The stifle joint is a complex, condylar synovial joint. It's consists of three joints articulation; femorotibial, femoropatellar, and tibiofibular. The knee joint acts as a pivot between the two long bones while the strongest muscles in the body, the quadriceps muscle, act across it. The femorotibial joint primary motion is hinge-like rotaion in saggital plane; to produce flexion and extension motion. The roller-like femoral condyles are roll and slide on the flattened condyles of the proximal tibia (Carpenter and Cooper, 2000; Hazewinkel et al., 2008a; Evans and Lahunta, 2013). The complex three-dimensional motion of the femorotibial joint can be described through six degrees of freedom including three rotations and three translations (Figure 1). The femoropatellar joint is a saddle joint which located between the patella and the femoral trochlear. The femorotibial and femoropatellar joint are involved in stifle flexion and extension. These are interdependent in that the patella is held firmly to the tibial tuberosity by patellar tendon so that any movement between the femur and the tibia also occurs between the patella and the femur (Evans and Lahunta, 2013). The patella move as proximo-distal gliding motion on trochlear groove of the femur associated with stifle extension or flexion. In human, the normal pattern of patella throughout stifle flexion and extension in frontal plane seem like a C-curve pattern (Hungerford and Barry, 1979). The complexity of stifle joint behavior is a result of interaction between three different factors including the static stability (geometry and anatomy of the joint surfaces), the active stability (i.e. muscle contraction), and the passive stability (i.e. ligaments, meniscus and retinacula). The in-depth knowledge of patellar motion in canine is still unclear.

The patella is an ossified portion of the large extensor muscle group of stifle joint, the quadriceps femoris muscle. It's a largest sesamoid bone in the body. It is ovoid, smooth and convex shape as to articulate with trochlear of femur. There are medial and lateral parapatellar fibrocartilages which are articulated with the trochlear ridges (Carpenter and Cooper, 2000). Moreover, the lateral and medial fascia lata are also held the patella firmly in the femoral trochlea. Although the patella is a passive body structure, it plays an important role in a dynamic system referred to as the extensor mechanism of the stifle joint. The patella provides cranial and rotary stability to stifle joint and protects the quadriceps tendon during movement. The patella alters the direction of pull of the tendon of the quadriceps. It protects and provides a greater bearing surface for the quadriceps tendon.

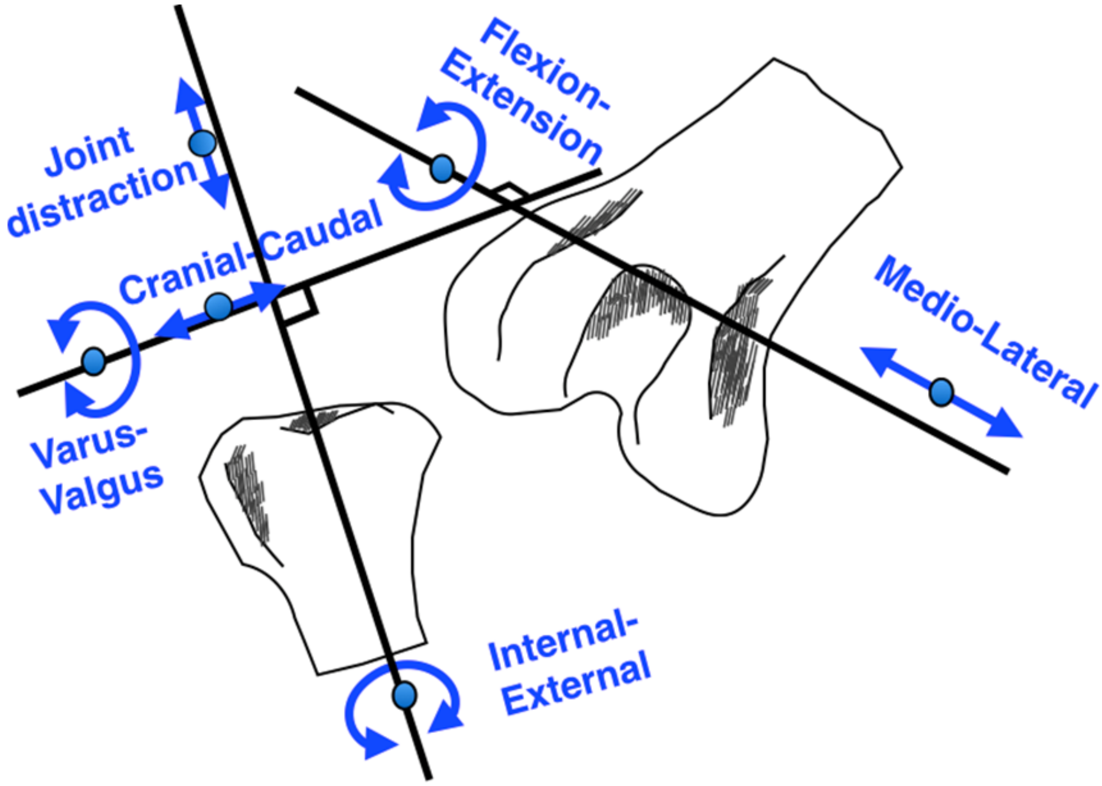




**Figure 1** The diagram of six degree of freedom of femorotibial joint motion expressed in a joint coordinate system. Flexion-extension and medial-lateral translation and occur about and along the epicondylar femoral axis. Cranial-Caudal translation and varus-valgus rotation occur along and about a floating axis, which is perpendicular to both femoral epicondylar axis. Internal-external rotation and joint distraction occur about and along the tibial long axis.

The quadriceps femoris muscle is primary extensor muscle group of stifle joint. The quadriceps muscle group covers the femur cranially, medially and laterally. There are four subdivisions of the quadriceps femoris muscle form the bulk of the group. Three of the four muscles originate from the proximal femur including the vastus lateralis, the vastus intermedius and the vastus medialis. Another muscle is the rectus femoris which originates from the ilium. These quadriceps muscle group converge on the patella and continues as the patellar ligament to insert on tibial tuberosity (Evans and Lahunta, 2013).

The knowledge of the biomechanics of stifle joint movement is essential in the treatment of patellar dysfunctions. The moment of a force is a measure of its tendency to cause a body to rotate about a specific point or axis. The magnitude of the moment of force acting about a point of center of rotation is directly proportional to the perpendicular distance (*d,* moment arm) between the point and the line of action of force (*F*). The measure of moment given by

$$\text{Moment} = Fd$$

Even the quadriceps muscle contracts then produces the pulling force on the patella throughout the patella ligament and the tibial tuberosity, the stifle joint will be extended. The main biomechanical function of patella is to improve the quadriceps efficiency by increasing moment arm of stifle extensor mechanism and thus the patellar tendon moment of force (Roush, 1993; Kowaleski et al., 2012). In case of patellectomy, the moment of quadriceps muscle force to extend stifle joint is decreasingly when compared with normal patellar because of its shorter moment arm (Figure 2). Moreover, if the moment is to be taken about a point due to a force and the line of action passes through that point, the total moment is zero because of the moment arm was zero. The closer the tension force being to the center of rotation, the less extension angle is possible (Weigel and Millis, 2014). Thus, the stifle joint cannot extend in the case of severe patellar luxation with permanently patellar dislocation and severe quadriceps malalignment. Because the moment of quadriceps extensor muscle force, relative with the moment arm, is nearby zero (Figure 3).

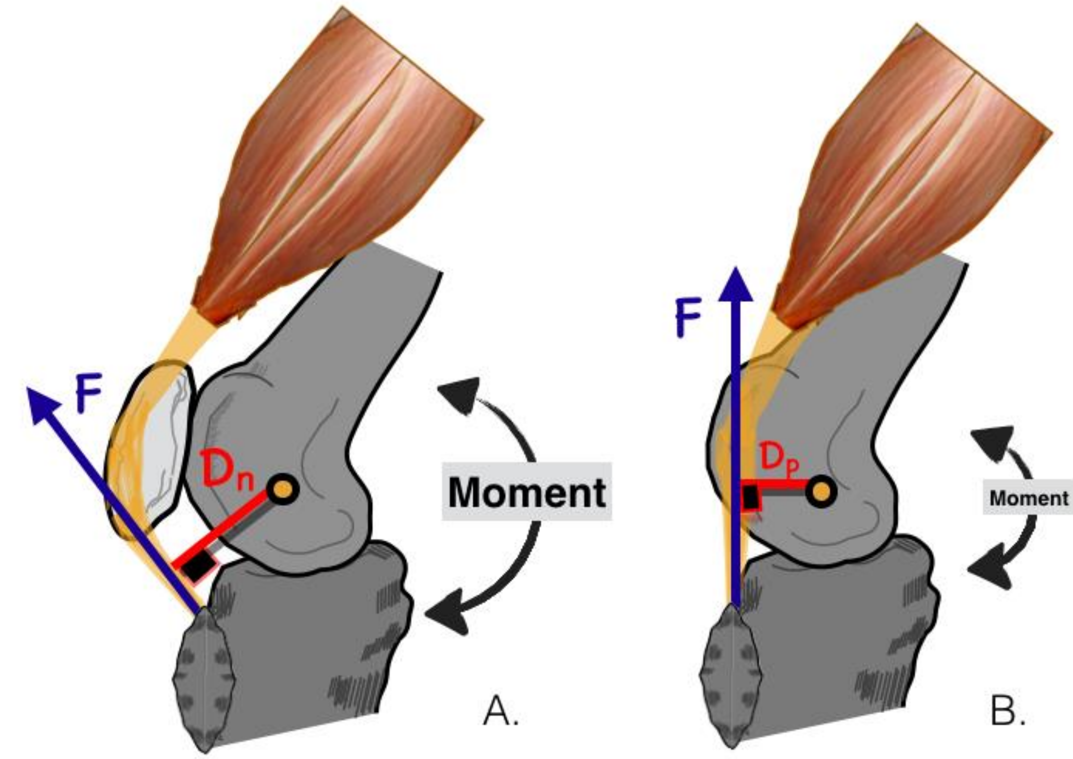


**Figure 2** The diagram of the joint moment of stifle extension in normal and patellectomy stifle. A. Normal patella B. Patellectomy. F: Quadriceps muscle force, Dn: moment arm of normal patella stifle, Dp: moment arm of patellectomy stifle. The moment of quadriceps muscle force to extend stifle joint is decreasingly in patellectomy stifle; because of its shorter moment arm (Dn<Dp).

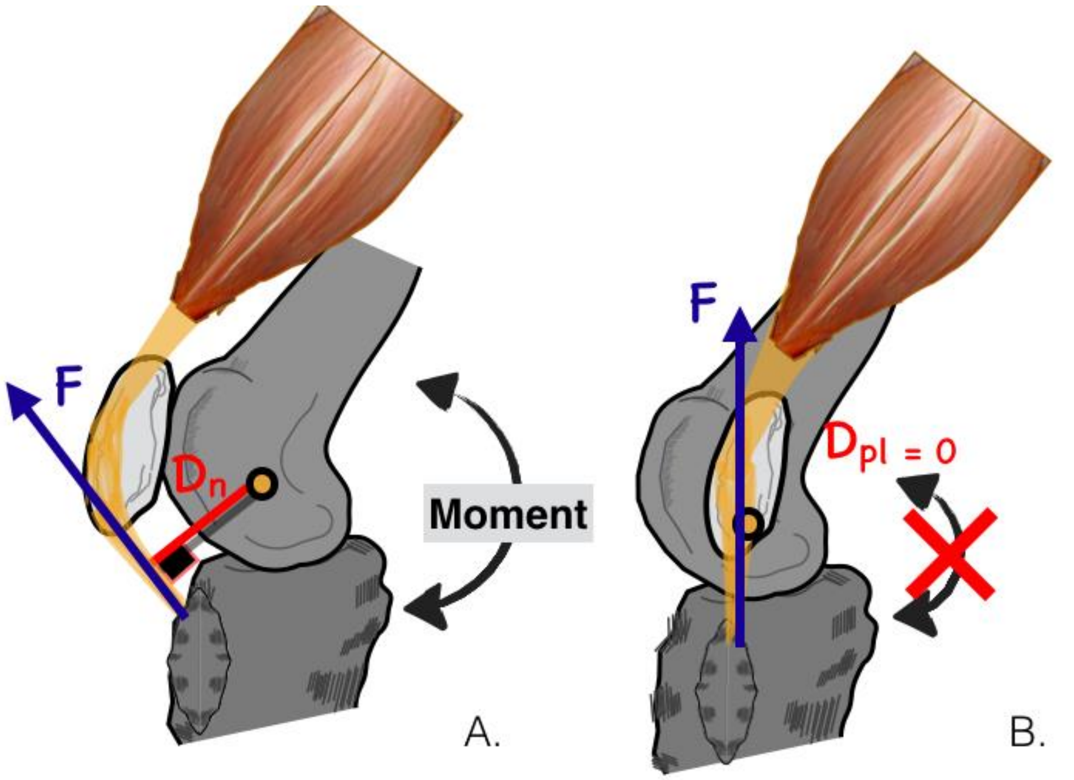


**Figure 3** The diagram of the joint moment of stifle extension in normal and medial patellar luxated stifle. A. Normal patella B. Patellar luxation. F: Quadriceps muscle force, Dn: moment arm of normal patella stifle, Dpl: moment arm of patellar luxation affected stifle. The moment of quadriceps muscle force to extend stifle joint is nearby zero in severe patellar luxation affected stifle (Dpl = 0). The stifle range of motion is decreased or eliminated in patellar luxated stifle.

Proper articulation and movement of the patella within the femoral trochlear groove requires complex interplay between the following 4 factors: limb alignment, articular geometry, dynamic muscular stabilizers, and passive ligamentous stabilizers. Abnormalities in one or more of these factors can result in predispose to clinically relevant patellar dislocation. In the patellar luxated case, the moment arm of the tension force in the quadriceps is reduced or eliminated. Moreover, the quadriceps might not stretch during stifle joint flexion and the joint also cannot be effectively extended. Loss of joint motion of stifle joint occurs. Approximately 50-60 degree of extension lost within a few months and appear to have a crouching gait (Marcellin-Little et al., 2015). Therefore, surgical correction to restore the alignment of the extensor mechanism is necessary for joint stabilization.

During quadriceps contraction, the extensor mechanism must be aligned within the trochlear groove of the distal femur. The normal position of the patella creates an effective moment by the quadriceps about center of rotation of the stifle joint such that extension of the stifle is maintained enough to bear weight. Whereas the forelimbs are the majority of the static weight bearing of the dog, the hind limb is the necessary for propulsion in dynamic activity such as running and jumping (Gillette and Angle, 2014). When a dog is bearing weight in the hind limbs, the antigravity muscles are resist to ground reaction force by contraction (Canapp, 2007). The main antigravity muscle groups for closed-chain function in the hind limb are digit flexors, talocrural extensors, stifle extensors, hip extensors in the sagittal plane and hip adductors in the frontal plane. The primary movers for hind limb muscles are showed in table 1. The normal stance posture creates a constant requirement for large hip extensor and stifles extensor moments. In this thesis, we focus on the muscle of stifle joint.

In part of the stifle extensor muscle group of hind limb, The quadriceps femoris is mainly stifle extensor muscle in conjunction with the cranial part of the sartorius, cranial part of the biceps femoris and the tensor fasciae latae (Evans and Lahunta, 2013). The sartorius, the biceps femoris and the tensor fasciae latae are the rump muscles which are weakly extend stifle. The sartorius, biceps and tensor fasciae latae muscles can also move the hip joint and the stifle joint, but all of its actions on stifle are weak, making it just a synergist muscles. The cranial part of sartorius insert on patella along with quadriceps tendon. The cranial part is union with the tendon of the rectus femoris and the vastus medialis and its contraction is contributing the stifle to extension during stance (Wentink, 1976; Evans and Lahunta, 2013). The biceps femoris is composed of multiple parts and difference action. The cranial parts of biceps femoris acts as mild extend the hip and stifles (Evans and Lahunta, 2013). The tensor fasciae latae muscle insert toward the stifle on the lateral surface of the vastus lateralis. It's function to flex the hip, abduct the limb and also slightly extend the stifle joint.

In the part of stifle flexor muscle groups of hind limb, the hamstring is the mainly stifle flexor muscle groups. The hamstrings lining through the hip and the stifle joint are therefore involved in stifle flexion and hip extension. The stifle flexor muscles are caudal part of biceps femoris, semitendinosus, caudal head of semimembranosus and caudal part of sartorius muscles. The caudal part of the biceps femoris muscle associated with stifle flexion at the start of the swing phase of locomotion and the tarsal joint extension (Wentink, 1976; Evans and Lahunta, 2013). The semitendinosus muscle flexes of the stifle in the free non-weight-bearing limb and extends the hip and tarsal joints. The caudal head of semimembranosus can flex the stifle and contribute to hip extension in locomotion (Peters and Rick, 1977). The caudal part of Sartorius is flex the hip and stifle while the limb is being protracted (Wentink, 1976).

**Table 1** The action of hind limb muscle groups (Evans and Lahunta, 2013)

| Muscle group | Muscle |
|---|---|
| Hip extensors | gluteal muscles, biceps femoris, semitendinosus, semimembranosus |
| Hip flexors | iliopsoas, sartorius, tensor fasciae latae |
| Hip adductors | adductor magnus et brevis, pectineus |
| Hip abductors | middle gluteal |
| Hip lateral rotators | internal and external obturator, gemelli |
| Hip medial rotators | deep gluteal, semitendinosus |
| Stifle extensors | quadriceps femoris, cranial part of sartorius, tensor fasciae latae, cranial part of biceps femoris |
| Stifle flexors | biceps femoris, semitendinosus, semimembranosus |
| Talocrural extensors | gastrocnemius, superficial digital flexor |
| Talocrural flexors | cranial tibial |
| Digit extensors | long digital extensor |
| Digit flexors | superficial and deep flexor |

## 2.3 Kinematic motion analysis

### 2.3.1 Definition of kinematic motion analysis

Kinesiology is scientific study of body movement. The motion analysis has become an investigative and diagnostic tool. There are two main ways to assess body movement. Firstly, the subjective evaluation which is a qualitative measurement of canine has been used for many years. The subjective lameness scoring is a frequently utilized scale in an attempt to describe lameness and changes in gait of canine patients. The visual analogue score is an easy tool and its practical to use in routine has several limitations. It is carried out by the human perceptive skill. Observers must be the same during the duration of a study for accurate analysis. This method usually occur the inter- and intra-observer variability (Gillette and Angle, 2008; Waxman et al., 2008; Miqueleto et al., 2013). It leads to negative effect on the diagnosis treatment and follow up after surgery. The mild conditions may still remain undetected (Quinn et al., 2007). Secondly, the quantitative measurements that used in the description and analysis of any movement are kinetic, kinematic analysis and electromyography. Kinetics is the study of forces that cause motion and kinematics is a study of the geometric characteristics of motion (McLaughlin, 2001). Moreover, the combination of kinetic, kinematic and morphometric data contribute an inverse dynamics analysis which provides more information about the mechanical events occurring around a specific joint during each phase of the gait.

The techniques of motion analysis have become the most productive tools to investigate normal and pathological gait in veterinary medicine. Subjective lameness scoring and kinetic analyses have been deemed valuable in evaluating treatment for patellar luxation in dogs. There was established that the qualitative lameness score was significantly improved from 4 weeks after surgery in MPL Pomeranians undergoing surgical correction (Wangdee et al., 2013). However, human perceptive skill to perceive subtle change during motion is limited and the personal impression is not feasible. On the other hand, objective gait evaluation is more efficient and precise than the subjective gait evaluation (Gillette and Angle, 2014). The technologic advances in computer-assisted gait analysis have aided our ability to quantitatively define the gait characteristics. The gait analysis leads researchers and practitioners to gaining an overall better understanding of canine gait and locomotion. The canine kinetic and kinematic gait analyses are developed for the objective description of movement for the study of musculoskeletal disease and lameness. It provides quantifiable, objective and repeatable information on normal and abnormal gait in dogs and the data collection requires specific equipment to obtain the accurate measurement. The use of gait analysis to evaluate individual clinical patients with lameness is becoming more valuable. These techniques might enable veterinarians to accurately diagnose subtle lameness, better evaluate dogs with resolving lameness, and accurately select the appropriated time to return an athletic dog to exercise after recovery from an injury (McLaughlin, 2001). Several researchers evaluated post-operative quantitative functional outcome by investigating weight bearing force during trotting using kinetic gait analysis to eliminated subjective bias. Peak vertical force and vertical impulse anaylysis by force platform system have been used to determination of post-operative outcome (Ballagas et al., 2004; Voss et al., 2008; Galindo-Zamora et al., 2014). However, there is rarely publication about kinetic study in MPL affected dogs. A researcher demonstrated that post-operative weight bearing force noticeable fluctuate in affected MPL dogs (Wiputhanuphongs et al., 2015). Although post-operative outcomes showed improvement of lameness signs by returning to nearly normal weight bearing, still cannot assume that the joint motion of affected limb also fully return to normal function. This consideration suggests that using kinetic along with kinematic tools is effectiveness for complete description of gait analysis.

Kinematic motion analysis explains the movement of body segment in space without reference to force. It can provide information relative to dynamic joint movement relative to dog’s stride. The linear and angular displacements, velocities and acceleration of each joint evaluated. Kinematic system using high speed cinematography integrated with computer software to detect markers and calculate for describes the body segment and the joint movement. Markers are placed on palpable bony landmarks: as the anatomical coordinate system. The coordinates are represent the center of joint rotation external spatial reference system (Gillette and

Angle, 2008). Computer programs are used to calculate the degrees of joint extension and flexion of subject passing through a testing area. There are several types of markers used. The non-reflective markers that employ delineation of color are recognized by the co-ordinate tagging system of kinematic computer programs. Another type of marker is reflective material markers. It reflects light back to the image source then be processed by the computer system. There are using of strobing LED markers, however, this type of marker requires that the patient must be tethered to the system (Gillette and Angle, 2008). Kinematic data collection can be performed in two or three dimension. A three dimension (3D) kinematic analysis generates image similar in depth as perceived by human vision, which has been accepted as a gold standard of gait analysis in human. However, this system still remains underused because it is too expensive to use in most general practices and it has relatively time-consuming to operate. An alternate method, a two-dimensional (2D) kinematic analysis, is easier to use and more economical compared with 3D analysis, allowing more practitioners to use this tool (Ugbolue et al., 2013; Gillette and Angle, 2014; Castelli et al., 2015). Kim et al. (2008) showed that a 2D system provides accurate and repeatable data of the sagittal angular motion of canine hind limbs during walking. Moreover, the amplitude of movement were predominates in the sagittal plane compared with transverse and longitudinal planes (Fu et al., 2010). The limitation of 2D analysis is that all motion takes place in only one plane. If the animal moves out of the calibration plane, the recorded motion capture data may be exaggerated or distorted (Miró et al., 2009). Some researchers have been used a treadmill locomotion to avoid this problems (Vilensky et al., 1997; Owen et al., 2004; Clements et al., 2005; Klinhom et al., 2015). Buchner et al. (1994) found differences exist between treadmill locomotion and over ground locomotion in horse. Anyway, Torres et al. (2013) found that in the sagittal plane of motion, no difference between over ground and treadmill-based gaits and produced similar waveform shapes of hind limbs joint movement in sagittal, transverse and frontal plane. Thus, the characteristic of the joint range of motion of dogs trotting on treadmill can be a good representation of dogs walking or trotting on natural over ground in sagittal plain.

The motion linkage among the multiple joints is producing the posture, gait and body movement. There are various forms of gait, which are a combined result of body anatomy and velocity of movement. It can be defined as symmetrical and asymmetrical. The symmetrical gait is the movements of the sides of the dog mirror each other such as walk, trot, and pace. The suitable gait to use for gait analysis is symmetry gait which easy to detect abnormal movement. In this gait, the movement of one side is mirroring the movement of another side. Walk is a four-beat gait which each paw placed separately. Pace is a two-beat lateral symmetrical gait, which unusually seen in small dogs breed with short-legged (Hildebrand, 1968). Trotting gait is a symmetrical gait produced when the diagonal pairs of limbs move almost simultaneously. Trotting is generally used to detect lameness because of greater forces place on that limb. In an asymmetrical gait, the movements of one side do not repeat those of the other. One full cycle of gait is referred to as a stride of each limb. A stride includes a single swing and stance phase of one foot. The stance phase of gait is the period when the foot remains on the ground. The stance phase divided into initial paw strike, braking, propulsion and then toe off. The swing phase occurs when the foot is off the ground between stance phases. This phase has three distinction movements. The limb swing caudally after propulsion after that pulled to cranially then caudally toward the ground to prepare for the next stance phase (Gillette and Angle, 2014).

### **2.3.2** Clinical applications of kinematic analysis

Kinematic studies have been show the normal angles of the joints go through during both the stance and swing phases and have been used to assess the kinematic changes in dogs with stifle or coxofemoral disease (Bockstahler et al., 2007; Ragetly et al., 2012; Foss et al., 2013; Miqueleto et al., 2013). Breed specific kinematic studies adapted to breed conformation standards are necessary to explain how particular conformational features may affect the musculoskeletal function. Previous studies of kinematic gait analysis in various large breed dogs such as Belgian Shepherd, Greyhound, Labrador retriever and German shepherd show various posture and joint movement due to various body conformations (Owen et al., 2004; Clements et al., 2005; Bockstahler et al., 2007; Miqueleto et al., 2013). Klinhom et al. (2015) studied the active range of motion (AROM) of forelimb and hind limb in walk pattern and trot pattern of Chihuahua dogs affected and non-affected with patellar luxation. This study shows a baseline kinematic study in Chihuahua conformation. For movement on a treadmill, habituation is the point at which a steady, repeatable gait is achieved. In greyhound, after walking for two minutes over the treadmill, consistent elbow and stifle joint kinematics at a trot can be obtained for treadmill-naïve Greyhound (Owen et al 2004). In Labradors Retrievers, a consistent trotting gait was not obtained after five two-minute trials over a treadmill (Clements et al., 2005). In healthy and MPL affected Chihuahuas can habituate after training to trotting on treadmill approximately 5-10 sessions per day, every 2 days for month (Klinhom et al., 2015). It was believed that the AROM was directly caused by patellar luxation disease and not from muscle fatigue. The animal forward velocity reported in the literature at a trotting gait. ranges from 1.1-2.4 m/sec (Owen et al., 2004; Miqueleto et al., 2013; Klinhom et al., 2015) However, absolute gait velocities vary with the size of the subject, with small animals ambulating slower than large animals.

**2.3.3** Parameters measured and joint range of motion analysis

The joint motion defined as the degree of motion that occurs when the bone comprising a joint move joint axis. The osteokinematic terms, such as flexion or extension, abduction or adduction, were used to name the movements that occur between bones at synovial joints. These terms describe the movements that occur around a center of rotation (Millis and Levine, 2014b). Joint motion data can be evaluated during static and dynamic joint movement. In general practice, the joint motion generally evaluates during the static which is measured by a goniometer. This tool produces passive range of motion (PROM) data. Dogs should be relax and plays no active role in producing the motion. Sometimes, the animals may be required to restrain or sedate and placed in lateral recumbence with the affected limb up and be measured. The PROM baseline in large breed have been documented in Labrador retrievers (Jaegger et al., 2002). The maximal extension joint angle (MFA), maximal flexion joint angle (MEA) and passive range of motion (PROM) were published. The range of motion during gait; in term of dynamic joint range of motion or active range of motion (AROM), is calculated when the animal is able to move on its own and show dynamic joint movement. This provides the examiner with the dog's willingness to move the joint. The dynamic joint movement achieved by active muscle contraction. Each joint has a characteristic pattern of flexion and extension movement for a defined gait. When a joint flexes, the numeric value of the joint angle is decreases. When a joint is extending, the numeric value of joint angle increases. The maximum angles of extension and flexion are those angles of the greatest joint excursion. Joint range of motion can be measured by subtracting the maximum flexion angle during gait from the maximum extension angle during gait cycle and reported in degrees of AROM (Millis and Levine, 2014a).

# CHAPTER 3
# MATERIALS AND METHODS

## **3.1** Animal

Chihuahua dogs were prospectively enrolled in the study. The dogs were included from the small animal teaching hospital, faculty of veterinary science, Chulalongkorn University. They received the standard care for spontaneously occurring diseases and evaluated according to standard orthopedic protocol. The permission of the owner was obtained prior to study to allow their dogs enrolled in the study. This study was conducted in accordance with the guidelines for the care and use of laboratory animals, and approved by the laboratory animal ethics committee of the faculty of veterinary science, Chulalongkorn university (approval No. 163121), Bangkok, Thailand. All dogs were healthy and no history of any other orthopedic problems. Both hind limbs were examined for all joints both in standing posture and in lateral recumbency. The stifle joints were examined for patellar luxation in medial and lateral direction. Dogs that have risk of exercise intolerance and suffer from other diseases were excluded. Dogs with some orthopedic problems such as avascular necrosis of the femoral head, coxofemoral osteoarthritis, and cranial cruciate ligament disease were also excluded from this study. All dogs were trained to walk and trot on treadmill before evaluation. Along period of study, the dogs that could not trot on treadmill, suffer from severe lameness or have recurrent patellar luxation were also excluded.

### **3.1.1** Normal group

Healthy Chihuahuas were 1-5 years of age were enrolled for this study, They were examined as normal for physical, orthopedic, and neurologic. Additionally, their history did not reveal any previous orthopedic or neurologic disease.

**3.1.2** Medial patellar luxation group (MPL group)

Chihuahuas examined and diagnosed with grade 3 medial patellar luxation were included in this group (Kowaleski et al., 2012).

**3.2** Study protocol

**3.2.1** Anesthesia protocol and surgical procedure

The dogs with MPL received the standard anesthesia and analgesia protocol for surgical correction as described in table 2.

**Table 2** Standard anesthesia and analgesia protocol for orthopedics surgery

| Procedure | Drug | Concentration | Dose | Route |
|---|---|---|---|---|
| Premedication | Acepromazine | 1 mg/ml | 0.03 mg/kg | Intramuscular (combined) |
| | Morphine | 10 mg/ml | 0.5 mg/kg | |
| Induction | Propofol | 10 mg/ml | 2-4 mg/kg | Intravenous |
| Maintenance | Isoflurane in 100% oxygen | | 1-4 mg% | Inhalation |
| Epidural nerve block | Bupivacaine | 5 mg/ml | 1 mg/kg | Epidural |
| Antibiotics prophylaxis | Cefazolin | 250 mg/ml | 25 mg/kg | Intravenous |

All dogs with grade 3 MPL were received surgical treatment by the two surgeons (KS[1], CW[2]). All Chihuahuas with grade III MPL were performed surgery on left legs as a first leg and the data were collected only on this leg. Trochlear block recession and tibial tuberosity transposition were the main procedures for surgical correction. Additional techniques of soft tissue reconstruction including medial desmotomy, lateral retinacular imbrication, and lateral patellar and tibial antirotational sutures were performed in some cases according to assessment during sugery. All techniques followed to Piermattei et al. (2006).

*Stifle joint approach*

Standard surgical preparation for orthopedic procedure was used before position dogs in lateral recumbence with affected limb upper suspended for draping. Skin and subcutaneous incision started lateral to the patellar ligament at one third of distal femur and continue to above tibial tuberosity. The lateral arthrotomy was performed by cut through lateral retinacular fascia, lateral fibrocartilage and joint capsule. The incision was approximately 5 mm parallel to the patella to explore the joint (Figure 4).

**Figure 4** Craniolateral approach to stifle joint

[1] KS Kumpanart Soontornvipart*, D.V.M., PhD.*

[2] CW Chalika Wangdee, *D.V.M.*, M.Sc. *PhD.*

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*Trochlear block recession*

Two osteotomy incisions of medial and lateral of trochlear ridges with 10 degree deviation in cartilage and bone to allow widest new trochlear groove were made along the length of sulcus (Figure 5). Bone and subchondral bone above condyle was removed to provide wide and length the groove at the proximal part.

**Figure 5** Trochlear block recession technique

*Tibial tuberosity transposition*

An incision is made in the periosteum medially along the tibial tuberosity and crest; leaving the distal bone and periosteum intact (Figure 6). Then, the tibial tuberosity was relocated to slightly to lateral. The pin was driven from near cortex through the thickest part of the tubercle in a slightly proximal and caudomedial direction. The pin engaged the far cortex to avoid pin migration.

**Figure 6** Tibial tuberosity transposition technique

*Medial desmotomy*

The medial tissue was released start from distal at proximal tibia at 2-3 mm medial to the edge of patellar ligament and continue to proximal at level of medial edge of patella (Figure 7). The quadriceps femoris muscle was released by incision the femoral fascia between vastus medialis muscle and the caudal part of sartorius muscle until the tension on patella was relieved.

**Figure 7** Medial desmotomy

*Lateral imbrication*

Joint capsule and fascia lata were imbricated with overlapping suture pattern by size 4-0 polydioxanone suture (Figure 8). If redundant joint capsule is presented, a partial capsulectomy was be performed, and imbrication was be accomplished on the remained capsular tissue. The fascial of muscle was imbricated with a vest-over-pants pattern combination with simple continuous pattern; 3-0 polydioxanone suture. If redundant fascia is present, a fasciectomy was performed.

**Figure 8** Lateral imbrication

**3.2.2** Post-operative management

The operated dogs received the post-operative management protocol as described in table 3. Physical therapy program was consisted of cryotherapy (15-20 minute, BID-TID) and gentle passive range of motion within easy comfortable range (15-30 repetitions, BID-TID). The dogs were restricted to short leash walk and control exercise for 6 weeks.

**Table 3** Post-operative management protocol

| Procedure | Drug | Concentration | Dose | Route |
|---|---|---|---|---|
| Analgesia | Firocoxib | 57 mg/tablet | 5 mg/kg sid 10 days | Per oral |
| Antibiotic | Cephalexin | 50 mg/ml | 25 mg/kg bid 7days | Per oral |

**3.3** Experimental design

**3.3.1** Kinematic motion analysis

*Training to trot on treadmill protocol*

All dogs were trained how to walk and trot on treadmill (Fairtex model ADT 150B, China) in order to allow them to get familiar with environment and experiment for data collected protocol (kinematic gait analysis). The training protocol was adapted from Miqueleto et al. (2013) and Klinhom et al. (2015). All dogs were trained at a frequency of 5-10 sessions per day for approximately 3-5 minutes per session, with 2-3 repetition and they were held on a leash by the same experience handler in the same manner (Figure 9). Each session had 30 minutes of resting period. The dogs were initially accustomed to walk on the treadmill. If they were rapidly familiar with the treadmill, they would start trotting on the same day. The treadmill was set at a low speed and increased gradually until the dogs achieved the trotting gait. The velocity of treadmill was maintained at approximately 1.11 meters per second for trotting.

**Figure 9** Training to trot on treadmill and tag the markers on hind limb

*Markers Placement*

Spherical non-reflective markers (Figure 10), 10 millimeters in diameter, were tagged to the skin on lateral aspect of limb over specific anatomical landmarks. The marker locations were inspected and palpated by the same researcher (KC)[3]. Dogs were clipped hair for clearly define the marker application points. On the hind limbs, markers were placed over specific anatomical landmarks comprise the distolateral aspect of the 5th metatarsus, the lateral malleolus of the distal fibula, lateral femorotibial joint (between the lateral femoral epicondyle and fibular head), the greater trochanter of the femur and dorsal iliac crest as shown in Figure 11. Manual joint flexion and extension after apply markers were used to verify marker positions. The markers are replaced every session by the same researcher.

**Figure 10** The spherical non-reflective markers

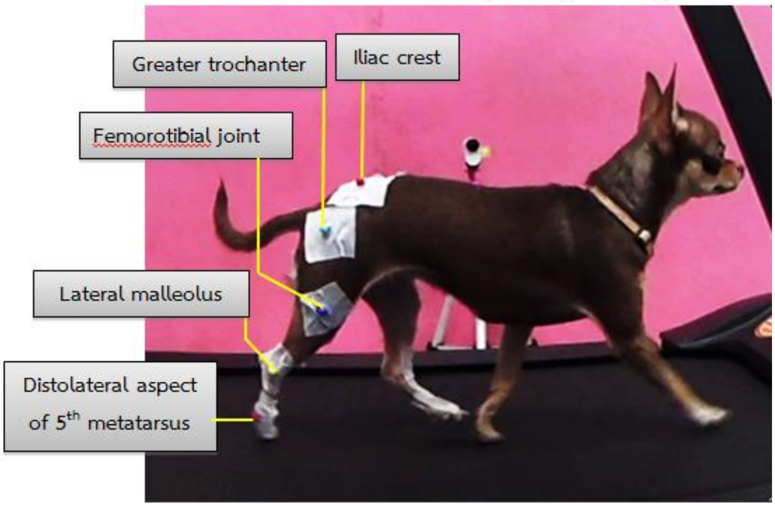


**Figure 11** The specific anatomical landmarks

[3] KC Kannika Chayatup, D.V.M., Department of Veterinary Surgery, Faculty of Veterinary Science, Chulalongkorn University

*Video capture system*

Two-dimensional kinematic data were collected by using two cameras optical motion analysis system with spherical non-reflexive markers. Video was recorded with frequency of 120 frame rates and resolution 1280 x 720 pixels. The two digital cameras (AS200V, Sony Corporation, Japan) were placed 0.5 meter distance perpendicular on left, right side of treadmill to record in sagittal plane. The coordinate data were analyzed by using motion analysis computer software. Kinovea program (version 0.8.24) was used to collect and process kinematic data by identified and label an individual marker and register the coordinates of each marker for reconstruct the trajectory of each frame. 2D stick-diagram represented to the dog movement (Damsted et al., 2015; Klinhom et al., 2015). The rectangular checkerboard calibration was used correct the positive radial distortion artifact and set up the origin of coordinate (0,0) on video in every session of recording (Figure 12).

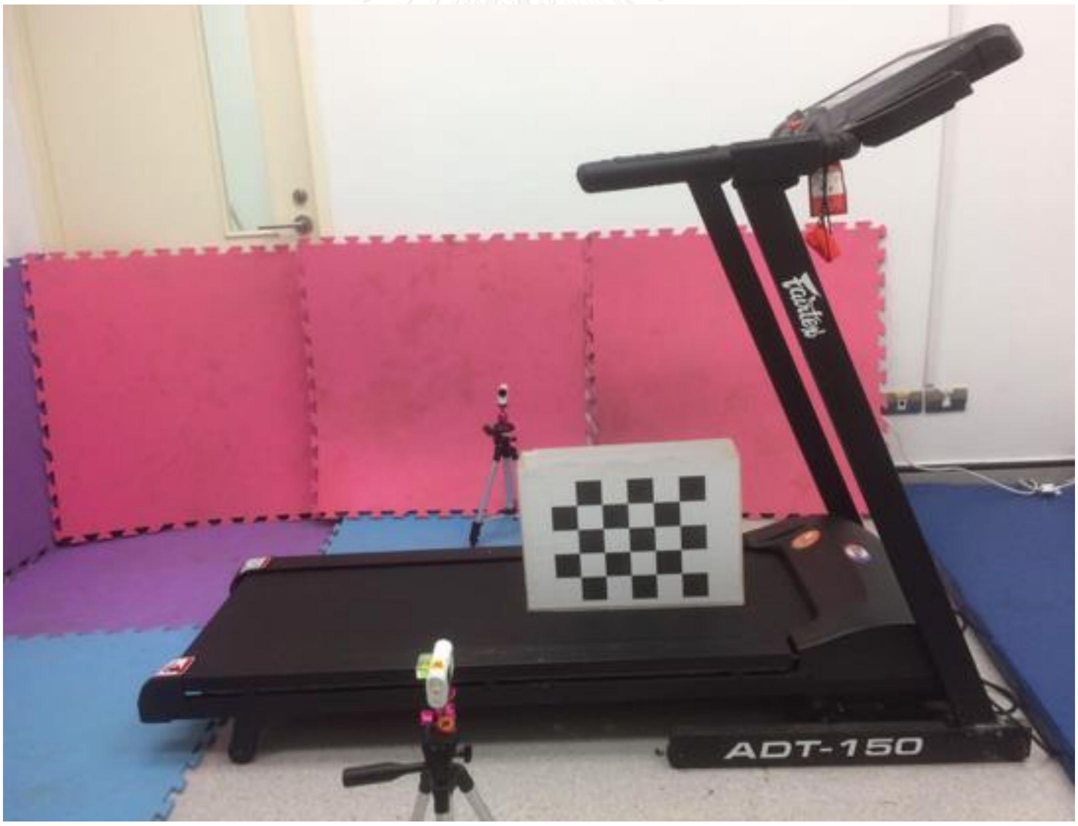


**Figure 12** The two-dimension kinematic analysis system

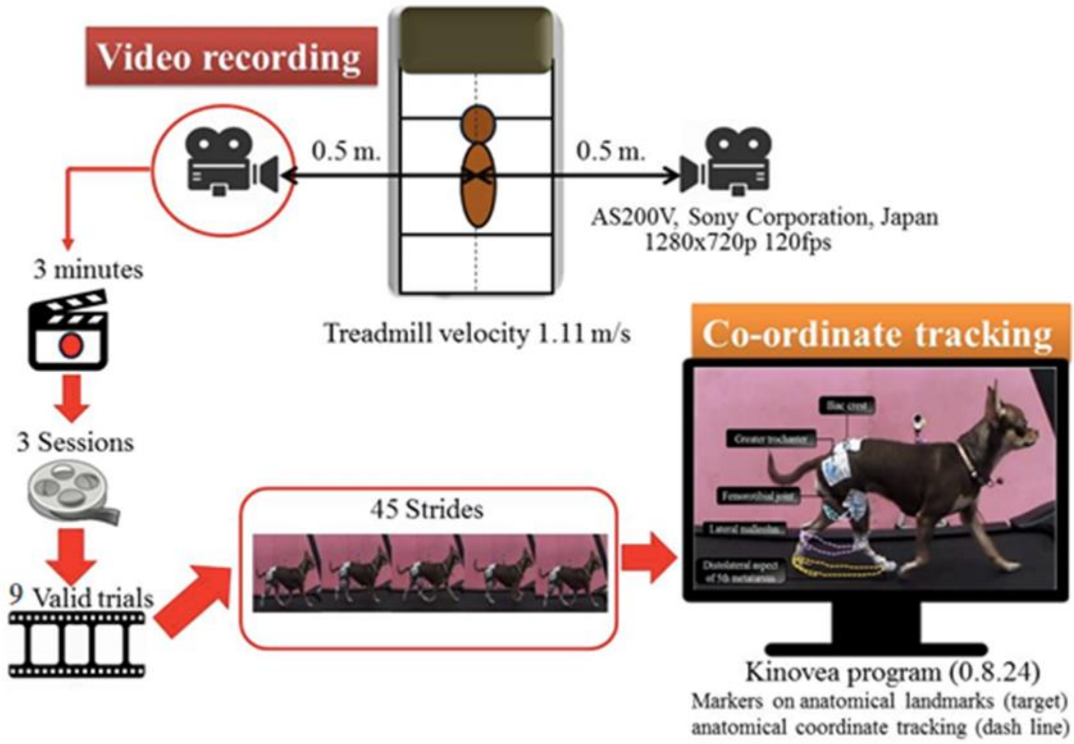


**Figure 13** The process of two dimensional kinematic motion analysis

*Kinematic data collection and analysis*

The MFA and the MEA were used to calculate the AROM during trotting in sagittal plane of each joint: hip, stifle and tarsus during trotting on treadmill. The treadmill was set at a low speed, without inclination and speed was increased gradually until the dogs achieved trotting gait and it was maintained at 1.11 meters per second.

In each period of kinematic data collection, a video was recorded 3 minutes during trotting. The video was divided into 3 sessions. In each session, 3 valid trials were examined. Each trial, consisting of 5 completed strides, was used to analyze MFA, MEA, and AROM (Figure 13). We archived the 3 sessions of kinematic data from normal group after the training program. In MPL group, kinematic data collection is performed before and after surgery at 2, 4, 6 and 8 weeks.

### 3.3.2 Goniometric Evaluation

Passive range of motions (PROM) of the hip joint, stifle joint and tarsal joint were measured by a goniometer in positions of maximal comfortable flexion and extension. The goniometer was placed over the fulcrum of the joints. The proximal arm of goniometer was placed parallel the proximal bone above the joint. The distal arm was placed parallel to the distal bone below the joint. The maneuver performing followed Jaegger et al. (2002). The joint was slowly flexed until an indicated sign of discomfort found, and then slowly extended until an indicated sign of discomfort. The maximal flexion angle, maximal extension angle and PROM were recorded.

### 3.3.3 Lameness evaluation

Subjective lameness scores from 0 to 5 were evaluated during walking and trotting by the same researcher (KC)[4]. Each score was described below (Hazewinkel et al., 2008b). (table 4)

**Table 4** Lameness score from 0 to 4 (Hazewinkel et al., 2008a)

| Lameness score | Definition |
|---|---|
| 0 | No lameness |
| 1 | Mild lameness; normal at a walk with mild lameness at a trot |
| 2 | Moderate lameness; consistent lameness at a walk with pronounced lameness at a trot |
| 3 | Severe lameness; toe-touching to some weight bearing at a walk and non-weight bearing trot |
| 4 | Non-weight bearing lameness |

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[4] KC Kannika Chayatup, D.V.M., Department of Veterinary Surgery, Faculty of Veterinary Science, Chulalongkorn University

### **3.3.4** Owner questionnaire

Owners were assigned to assess their dogs prior to surgery and at the time of follow in regards to quality of life, willingness to play voluntarily, activity level, stiffness at the beginning and at the end of the day, lameness on the surgical limb, and pain while the dogs walked on the surgical limb (table 5). Subjective scales from 0 to 5 presenting less to more were established.

**Table 5** Owner questionnaire

| Question | Level | | | | | |
|---|---|---|---|---|---|---|
| **PRIOR to surgery** | | | | | | |
| 1) How was quality of life? | 0 | 1 | 2 | 3 | 4 | 5 |
| 2) What was willingness to play voluntarily? | 0 | 1 | 2 | 3 | 4 | 5 |
| 3) How was activity during the day? | 0 | 1 | 2 | 3 | 4 | 5 |
| 4) Evidence of stiffness? | 0 | 1 | 2 | 3 | 4 | 5 |
| 5) Indication of lameness? | 0 | 1 | 2 | 3 | 4 | 5 |
| **AFTER surgical repair** | | | | | | |
| 1) What is quality of life now since surgery? | 0 | 1 | 2 | 3 | 4 | 5 |
| 2) What is willingness to play voluntarily? | 0 | 1 | 2 | 3 | 4 | 5 |
| 3) How is activity during the day? | 0 | 1 | 2 | 3 | 4 | 5 |
| 4) Evidence of stiffness? | 0 | 1 | 2 | 3 | 4 | 5 |
| 5) Indication of lameness on surgery limb? | 0 | 1 | 2 | 3 | 4 | 5 |

**3.4** Statistical analysis

The degree of MFA, MEA, AROM and PROM were reported as mean ± SD. Lameness score was repost as median (range). The normality test was used *Shapiro-Wilk test.* To compare the degree of MFA, MEA, AROM and PROM between left side and right side of the both limb in normal group, independent student's t-test was used for data analysis. The baseline degree of MFA, MEA, AROM, PROM of normal group (n=14 stifles) are presented as the mean ± SD. To compare the degree of MFA, MEA, AROM and PROM between the normal group and MPL groups, independent student's t-test was used for data analysis. To compare within MPL group between time points, the repeated measure ANOVA with a Greenhouse-Geisser and post hoc test using the Bonferroni correction were used. Statistical analysis was implemented by using the statistical package SPSS program (version 22.0.0, IBM Corp.). The significance level is set up at p-value < 0.05.

# CHAPTER 4
# RESULTS

## 4.1 Dogs

All seventeen dogs were enrolled and included in the study. Seven normal Chihuahuas including 4 males and 3 females (14 normal stifles) were in the control group. Mean+SD of age was 2.3+0.68 (range 1 - 5 years) and median of age was 2 years. Mean+SD of body weight was 3.20+0.55 (range 2.4 - 3.98 kg) and median of body weight was 3.12 kg. Median of body condition score was 5 (range from 4 to 6). The MPL group was consisted of 10 Chihuahuas dogs including 6 males and 4 females. Mean + SD of age was 2.7 + 1.34 (range 1 - 5 years) and median of age was 2 years. Mean + SD of body weight was 3.21+0.75 (range 2.0 - 4.3 kg) and median of body weight was 3.23 kg. Median of body condition score was 5 (range from 3 to 6). All dogs had bilateral grade III MPL. The distributions of age, sex, body weight, body condition score in control and MPL groups were shown in table 6 and 7, respectively. Age, sex, body weight, body condition score were not significant difference between both groups.



**Table 6** The distributions of age, sex, body weight, body condition score in normal group.

| Subject | Age (years) | Sex* | Weight (kg) | BCS (1-10) |
|---|---|---|---|---|
| **1** | 4 | Male(castrated) | 3.25 | 5 |
| **2** | 2 | Male | 3.98 | 6 |
| **3** | 2 | Female | 3.2 | 5 |
| **4** | 2 | Female | 2.9 | 5 |
| **5** | 2 | Male | 2.4 | 3 |
| **6** | 2 | Female(spayed) | 3.5 | 5 |
| **7** | 3 | Male | 2.8 | 4 |

**Table 7** The distributions of age, sex, body weight, body condition score in MPL group.

| Subject | Age (years) | Sex* | Weight (kg) | BCS (1-10) |
|---|---|---|---|---|
| **1** | 1 | Male | 3.68 | 5 |
| **2** | 3 | Female | 2.32 | 4 |
| **3** | 3 | Male | 3.45 | 5 |
| **4** | 2 | Female(spayed) | 3.5 | 5 |
| **5** | 2 | Male | 2.8 | 4 |
| **6** | 5 | Male | 4.3 | 6 |
| **7** | 2 | Male | 3 | 5 |
| **8** | 5 | Male | 4.18 | 5 |
| **9** | 2 | Female(spayed) | 2.88 | 4 |
| **10** | 2 | Female | 2 | 4 |

**4.2** Kinematic motion analysis

**4.2.1** Comparison between left and right limbs in normal group

No significant difference of MEA, MFA and AROM was found between right and left limbs in all kinematic variables in normal group. The MEA, MFA and AROM of both limbs (n=14 stifles) in normal group are presented as the mean ± SD in table 8.

**Table 8** Comparison of maximum flexion angle, maximum extension angle and active range of motion between right and left limbs in trot gait in normal group

| Joints and sides | MEA | *p*-value | MFA | *p*-value | AROM | *p*-value |
|---|---|---|---|---|---|---|
| **Hip** | | | | | | |
| Left | 138.11±13.12 | 0.73 | 119.61±11.70 | 0.78 | 18.51±2.98 | 0.49 |
| Right | 140.24±12.27 | | 121.13±11.26 | | 19.11±2.96 | |
| **Normal** | **139.18±11.20** | | **120.37±9.74** | | **18.81±1.56** | |
| **Stifle** | | | | | | |
| Left | 162.31±21.00 | 0.98 | 110.42±21.31 | 0.96 | 51.88±8.26 | 0.88 |
| Right | 162.16±17.24 | | 110.85±19.86 | | 51.31±9.95 | |
| **Normal** | **162.23±17.50** | | **110.63±18.13** | | **51.60±7.18** | |
| **Tarsal** | | | | | | |
| Left | 153.51±23.43 | 0.67 | 105.24±21.38 | 0.82 | 48.28±9.37 | 0.73 |
| Right | 150.34±25.86 | | 103.44±24.02 | | 46.90±10.69 | |
| **Normal** | **151.93±13.44** | | **104.34±14.16** | | **47.59±7.05** | |

The significantly different at *p*-value < 0.05

**4.2.2** Comparison between normal and MPL group

The mean ± SD of MEA, MFA and AROM in normal group (n=14) and MPL group (n=10) are presented in table 9. There were highly significant differences between normal and MPL dogs in some kinematic parameters. The degrees of MEA, MFA, and AROM of stifle joint in MPL group were significantly lower than those in normal group (p=0.001, 0.01 and 0.001, respectively). The AROM of tarsal joint and hip joint in MPL group were significantly higher than that in normal group (p=0.001 and 0.001, respectively). The MFA of hip joint in MPL group was significantly lower than that in normal group. The MEA and MFA of tarsal joint in MPL group were significantly higher and significantly lower than those in normal group, respectively with P-value of 0.001.

**Table 9** Comparison of maximum flexion angle, maximum extension angle and active range of motion between normal and MPL groups

| Joints& group | MEA | *p*-value | MFA | *p*-value | AROM | *p*-value |
|---|---|---|---|---|---|---|
| **Hip** | | | | | | |
| Normal | 139.18±11.20 | 0.20 | 120.37±9.74 | 0.001 | 18.81±1.56 | 0.001 |
| MPL | 143.94±2.96 | | 108.40±9.30 | | 35.53±10.67 | |
| **Stifle** | | | | | | |
| Normal | 162.23±17.50 | 0.001 | 110.63±18.13 | 0.01 | 51.60±7.18 | 0.001 |
| MPL | 125.65±1.63 | | 96.88±1.31 | | 28.77±2.29 | |
| **Tarsus** | | | | | | |
| Normal | 151.93±13.44 | 0.001 | 104.34±14.16 | 0.001 | 47.59±7.05 | 0.001 |
| MPL | 166.20±5.84 | | 89.18±1.81 | | 77.02±5.73 | |

The significantly different at *p*-value < 0.05

**4.2.3** Comparison between normal group, pre- and post-surgical correction in MPL group

The comparison of mean ± SD of MEA, MFA and AROM of hip joint, stifle joint and tarsal joint of normal group, pre-operatively and at 2, 4, 6, and 8 weeks post-operatively in MPL group are presented in table 10-12.

In MPL group, the AROM of stifle joint had significantly increase at 2, 4, 6, and 8 weeks post-operatively when compare to pre-operatively ($p<0.05$). The AROM of hip joint at 8 weeks post-operatively was significantly lower than that pre-operatively and the tarsal joint had decrease of AROM at 2, 4, 6, and 8 weeks post-operatively when compare with pre-operatively.

In the stifle joint, the MEA had significantly increase at 2, 4, 6, and 8 weeks post-operatively when compared to pre-operatively ($p<0.05$). However, no significant difference of the MFA was found between pre-operatively and at 2, 4, 6, and 8 weeks post-operatively. Moreover, the MEA of hip joint had no significantly difference at 2, 4, 6, and 8 weeks post-operatively but the MFA of hip joint had significantly increase between pre-operatively and at 2, 4, 6 and 8 weeks post-operatively. Additionally, the MEA of tarsal joint had statistically decreased when compared between pre-operatively with at 2, 4 and 6 weeks post-operatively. The MFA of tarsal joint had significantly increased at 2, 4, 6, and 8 weeks post-operatively when compared to pre-operatively.

The AROM of stifle and tarsal joints in MPL group had no significant difference with normal group at 6 and 8 weeks post-operatively. The AROM of hip joint in MPL group had no significant difference with normal group at 8 weeks post-operatively.

The MFA of stifle joint in normal group had no significant difference with MPL group at 6 and 8 weeks post-operatively. The MFA of stifle joint in normal group was no significant difference with MPL group at 4 weeks post-operatively. There was not significant difference of MEA of hip joint among period of post-operative follow up as well as the MEA of hip joint in MPL group was not significantly different with normal group. The MFA of hip joint in normal group had no significant difference with MPL group at 8 weeks post-operatively. There was no significant difference of the MEA of tarsal joint in normal group and in MPL group at the period of follow up. There was no significant difference of the MFA of tarsal joint in normal group and in MPL group at 6 and 8 weeks post-operatively.

**Table 10** The comparison of maximum flexion angle, maximum extension angle and active range of motion of the hip joint in MPL group among pre-and at 2, 4, 6, and 8 weeks post-operatively.

| Group & Period | Hip joint | | | | | |
|---|---|---|---|---|---|---|
| | MEA | *P** | MFA | *P** | AROM | *P** |
| **Normal group** | | | | | | |
| | 139.18±11.20 | | 120.37±9.74 | | 18.81±1.56 | |
| **MPL group** | | | | | | |
| Pre-op. | 143.94±2.96 | 0.200 | 108.41±9.30 | 0.001 | 35.53±10.67 | 0.001 |
| 2 weeks post-op. | 144.01±2.06 | 0.130 | 110.54±9.44 | 0.020 | 33.47±10.65 | 0.002 |
| 4 weeks post-op. | 140.16±12.28 | 0.840 | 100.01±11.12 | 0.001 | 40.15±1.88 | 0.001 |
| 6 weeks post-op. | 134.95±12.52 | 0.390 | 110.02±11.21 | 0.025 | 24.93±1.79 | 0.001 |
| 8 weeks post-op. | 136.87±12.37 | 0.630 | 118.21±10.92 | 0.610 | 18.67±1.64 | 0.820 |

* p-value shows the difference between normal and each period of follow up. The significantly different is at p-value < 0.05.

**Table 11** The comparison of maximum flexion angle, maximum extension angle and active range of motion of stifle joint in MPL group among pre-and at 2, 4, 6, and 8 weeks post-operatively.

| Group & Period | Stifle joint | | | | | |
|---|---|---|---|---|---|---|
| | MEA | *P** | MFA | *P** | AROM | *P** |
| **Normal group** | | | | | | |
| | 162.23±17.50 | | 110.63±18.13 | | 51.60±7.18 | |
| **MPL group** | | | | | | |
| Pre-op. | 125.65±1.63 | 0.001 | 96.88±1.31 | 0.010 | 28.77±2.29 | 0.001 |
| 2 weeks post-op. | 136.49±0.45 | 0.001 | 100.16±0.63 | 0.056 | 36.33±0.73 | 0.001 |
| 4 weeks post-op. | 145.44±20.69 | 0.040 | 100.12±20.71 | 0.200 | 45.33±7.02 | 0.040 |
| 6 weeks post-op. | 150.84±20.63 | 0.160 | 105.02±21.22 | 0.490 | 45.82±7.07 | 0.060 |
| 8 weeks post-op. | 158.97±20.15 | 0.680 | 108.29±20.56 | 0.770 | 50.67±6.93 | 0.760 |

** p-value shows the difference between normal and each period of follow up.*
*The* significantly different is at *p*-value < 0.05.

**Table 12** The comparison of maximum flexion angle, maximum extension angle and active range of motion of tarsal joint in MPL group among pre-and at 2, 4, 6, and 8 weeks post-operatively.

| Group & Period | Tarsal joint | | | | | |
|---|---|---|---|---|---|---|
| | MEA | *P** | MFA | *P** | AROM | *P** |
| Normal group | | | | | | |
| | 151.93±13.44 | | 104.34±14.16 | | 47.59±7.05 | |
| MPL group | | | | | | |
| Pre-op | 166.20±5.84 | 0.001 | 89.18±1.81 | 0.001 | 77.02±5.73 | 0.001 |
| 2 weeks post-op | 147.54±3.02 | 0.250 | 93.58±1.63 | 0.014 | 53.97±3.15 | 0.001 |
| 4 weeks post-op | 143.99±11.76 | 0.140 | 91.76±15.23 | 0.040 | 52.23±7.78 | 0.140 |
| 6 weeks post-op | 145.68±16.03 | 0.310 | 101.91±14.88 | 0.680 | 43.78±6.98 | 0.200 |
| 8 weeks post-op | 150.19±14.44 | 0.770 | 102.01±14.03 | 0.690 | 48.18±6.32 | 0.830 |

** p-value shows the difference between normal and each period of follow up.*
*The* significantly different is at *p*-value < 0.05.

### 4.3 Goniometric evaluation of joint

#### 4.3.1 Comparison between left and right limbs in normal group

The MEA, MFA and passive range of motion (PROM) in normal group and the significant level is set up at p-value < 0.05. In normal group, the joint angular motion of all three joints were not significant difference between the left and the right hind limbs. The MEA, MFA and AROM of both limbs (n=14 stifles) in normal group are presented as the mean ± SD.

**Table 13** The comparison of maximum flexion angle, maximum extension angle and passive range of motion between right and left limbs in normal group.

| Joints and sides | MEA | *p*-value | MFA | *p*-value | PROM | *p*-value |
|---|---|---|---|---|---|---|
| Hip | | | | | | |
| Left | 162.52±2.79 | 0.67 | 51.38±1.13 | 0.72 | 111.14±2.19 | 0.69 |
| Right | 161.81±1.13 | | 51.19±0.81 | | 110.62±2.53 | |
| **Normal** | **162.17±2.93** | | **51.29±0.95** | | **110.88±2.29** | |
| Stifle | | | | | | |
| Left | 161.81±3.26 | 0.16 | 45.57±1.51 | 0.92 | 116.24±3.67 | 0.31 |
| Right | 164.05±2.11 | | 45.67±1.95 | | 118.38±3.95 | |
| **Normal** | **162.93±2.88** | | **45.62±1.68** | | **117.31±3.82** | |
| Tarsal | | | | | | |
| Left | 168.95±2.24 | 0.75 | 37.33±0.88 | 0.92 | 131.62±1.50 | 0.73 |
| Right | 168.48±3.18 | | 37.38±0.89 | | 131.10±3.62 | |
| **Normal** | **168.71±2.66** | | **37.36±0.85** | | **131.36±2.67** | |

### 4.3.2 Comparison between normal group and MPL group

The mean of MEA, MFA and PROM in normal group and in MPL group are presented in table 14. The PROM and MEA of stifle joint in MPL group was significant lower than those in normal group (p=0.001). Nevertheless, there was no significant difference of MEA of stifle joint between MPL group and normal group. The PROM of tarsal joint in MPL group was significant lower than that in normal group (p=0.001). Conversely, the MFA of tarsal joint in MPL group was significantly increased. There was no significant of MEA, MFA and PROM of hip joint between normal group and MPL group.

**Table 14** The comparison of maximum flexion angle, maximum extension angle and passive range of motion between normal group and MPL group.

| Joints and sides | MEA | *p*-value | MFA | *p*-value | PROM | *p*-value |
|---|---|---|---|---|---|---|
| Hip | | | | | | |
| Normal | 162.17±2.93 | 0.29 | 51.29±0.95 | 0.67 | 110.88±2.29 | 0.64 |
| MPL | 160.87±2.18 | | 48.77±1.87 | | 112.10±7.80 | |
| Stifle | | | | | | |
| Normal | 162.93±2.88 | 0.001 | 45.62±1.68 | 0.77 | 117.31±3.82 | 0.001 |
| MPL | 149.70±3.61 | | 45.83±1.86 | | 103.60±4.06 | |
| Tarsal | | | | | | |
| Normal | 168.71±2.66 | 0.37 | 37.36±0.85 | 0.001 | 131.36±2.67 | 0.001 |
| MPL | 169.97±3.63 | | 47.13±5.13 | | 122.83±5.66 | |

MFA: Maximum flexion angle, MEA: Maximum extension angle, PROM: passive range of motion.

**4.3.3** Comparison between normal group, pre- and post-surgical correction in MPL group

The MEA, MFA and PROM in normal group and in MPL group are presented in table 15-17. In MPL group, the PROM of stifle joint was significantly increased at 6 week post-operatively when compared to pre-operatively (p=0.001) as well as the MEA of stifle joint was significantly increased at 6 weeks and 8 weeks post-operatively (p=0.02 and 0.01, respectively). The MFA was no significant difference between pre-and post-operatively (p=0.40). The PROM and MEA of stifle joint in normal group was significantly lower than those in MPL group at 2, 4, 6, and 8 weeks post- operatively (p=0.001,0.001,0.01 and 0.001, respectively); however, the MFA was not statistical difference between normal group and MPL group at 2, 4, 6, and 8 weeks post-operatively.

The degree of PROM was significantly decreased at 2 weeks post-operatively (*p*=0.001) then significantly increased at 4, 6 weeks and 8 weeks post-operatively when compare at 2 weeks post-operatively. (*p*=0.001, 0.001 and 0.001, respectively). In contrast with, the MEA of tarsal joint was significantly decreased at 2 weeks post-operatively when compared with pre-operatively, then significantly increased at 4, 6 and 8 weeks post-operatively when compared at 2 weeks post-operatively. There were significantly lower of the PROM of tarsal joint in normal group and in MPL group at 2, 4, 6, and 8 weeks post-operatively (*p*<0.05). There was no significant difference of the MEA of tarsal joint when comparing the normal group with MPL group at 6 and 8 weeks post-operatively (*p*=0.36 and 0.19, respectively). The MFA of tarsal joint in MPL group at 2, 4, 6, and 8 weeks post-operatively had significantly higher than that in normal group (**p**<0.05).

The MEA of hip joint was significantly decreased at 4 weeks post-operatively, and it had significantly increased at 6 and 8 weeks post-operatively when compare with pre-operatively. However, there was no significant difference between the PROM and MFA of hip joint between pre- and post-operatively (p=0.37 and 0.07, respectively).

**Table 15** The comparison of maximum flexion angle, maximum extension angle and passive range of motion of hip joint in MPL group among pre-and at 2, 4, 6, and 8 weeks post-operatively.

| Group & Period | Hip joint | | | | | |
|---|---|---|---|---|---|---|
| | MEA | *P** | MFA | *P** | AROM | *P** |
| Normal group | | | | | | |
| | 162.17±2.93 | | 51.29±0.95 | | 110.88±2.29 | |
| MPL group | | | | | | |
| Pre-op | 160.87±2.18 | 0.290 | 48.71±1.87 | 0.670 | 112.10±7.80 | 0.640 |
| 2 weeks post-op | 160.37±2.94 | 0.152 | 51.07±2.55 | 0.800 | 109.30±2.54 | 0.125 |
| 4 weeks post-op | 155.03±3.43 | 0.001 | 50.23±1.19 | 0.025 | 104.80±3.26 | 0.001 |
| 6 weeks post-op | 160.63±2.06 | 0.169 | 50.03±3.90 | 0.344 | 110.6±5.54 | 0.865 |
| 8 weeks post-op | 161.47±2.80 | 0.562 | 51.73±1.47 | 0.374 | 109.73±2.81 | 0.282 |

** p-value shows the difference between normal and each period of follow up.*

*The* significantly different is at *p*-value < 0.05.

**Table 16** The comparison of maximum flexion angle, maximum extension angle and passive range of motion of stifle joint in MPL group among pre-and at 2, 4, 6, and 8 weeks post-operatively.

| Group & Period | Stifle joint | | | | | |
|---|---|---|---|---|---|---|
| | MEA | *p** | MFA | *p** | PROM | *p** |
| **Normal group** | | | | | | |
| | 162.93±2.88 | | 45.62±1.68 | | 117.31±3.82 | |
| **MPL group** | | | | | | |
| Pre-op | 149.70±3.6 | 0.001 | 45.83±1.86 | 0.770 | 103.60±4.06 | 0.001 |
| 2 weeks post-op | 147.27±5.88 | 0.001 | 46.57±1.27 | 0.147 | 100.70±5.68 | 0.001 |
| 4 weeks post-op | 144.67±3.53 | 0.001 | 46.17±0.96 | 0.365 | 98.50±3.19 | 0.001 |
| 6 weeks post-op | 156.63±3.11 | 0.001 | 45.57±0.83 | 0.929 | 111.07±3.49 | 0.001 |
| 8 weeks post-op | 161.47±3.06 | 0.001 | 51.73±0.85 | 0.555 | 110.73±3.12 | 0.001 |

** p-value shows the difference between normal and each period of follow up.*

*The* significantly different is at *p*-value < 0.05.

**Table 17** The comparison of maximum flexion angle, maximum extension angle and passive range of motion of tarsal joint in MPL group among pre-and at 2, 4, 6, and 8 weeks post-operatively.

| Group & Period | Tarsal joint | | | | | |
|---|---|---|---|---|---|---|
| | MEA | *P** | MFA | *P** | PROM | *P** |
| **Normal group** | | | | | | |
| | 168.71±2.66 | | 37.36±0.85 | | 131.36±2.67 | |
| **MPL group** | | | | | | |
| Pre-op | 169.97±3.63 | 0.370 | 47.13±5.13 | 0.001 | 122.83±5.66 | 0.001 |
| 2 weeks post-op | 164.43±0.94 | 0.001 | 58.27±1.91 | 0.001 | 106.17±1.20 | 0.001 |
| 4 weeks post-op | 172.50±2.24 | 0.001 | 46.57±5.03 | 0.001 | 125.93±5.59 | 0.004 |
| 6 weeks post-op | 169.63±1.96 | 0.364 | 44.60±2.61 | 0.001 | 125.03±3.39 | 0.001 |
| 8 weeks post-op | 170.60±3.76 | 0.163 | 45.33±3.67 | 0.001 | 125.26±6.02 | 0.003 |

** p-value shows the difference between normal and each period of follow up.*
*The* significantly different is at *p*-value < 0.05.

**4.4** Lameness score

The median (range) lameness score of grade III medial patellar luxation cases prior to surgery was 1 (0-2). Lameness scores increased to 2.5 (1-3) at 2 weeks after surgery. The lameness score was significantly improved from 4 weeks after surgery until the end of the follow-up period in comparison with the pre-operative lameness scores in medial patellar luxation group (p <0.05) (Figure 14).

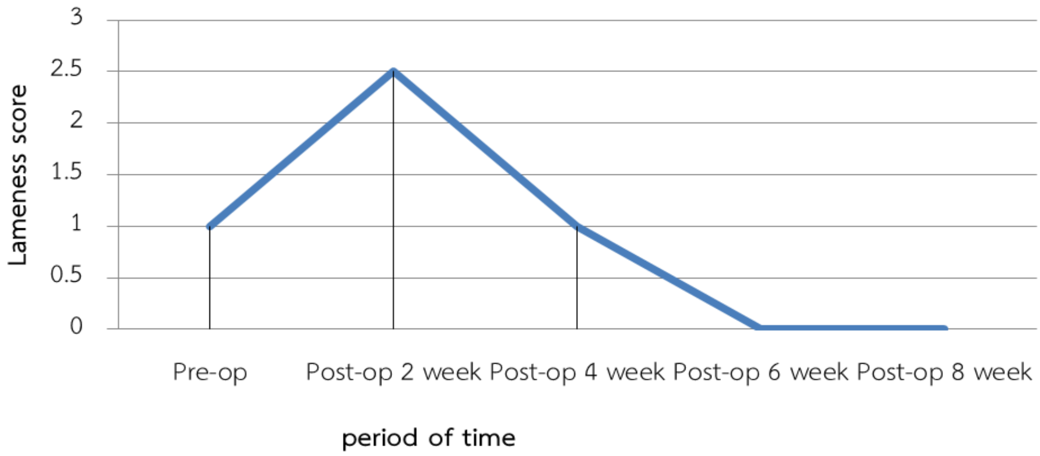


**Figure 14** The graph of lameness score in MPL group at pre-and at 2, 4, 6, and 8 weeks post-operatively.

**4.5** Owner questionnaire

The score of quality of life, voluntary to play, activity level, stiffness and lameness level assessed by the owners were shown in Figure 15.

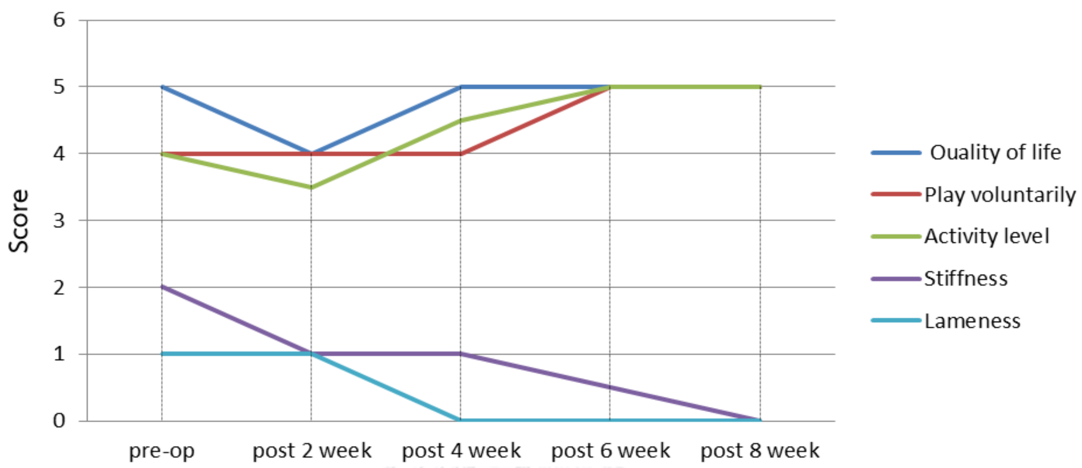


**Figure 15** The graph of level of owner’s impression on pre- and post-operation

# CHAPTER 5
# DISCUSSION

This study is the first to use kinematic motion analysis to investigate changes in joint motion pattern in dog suffering from MPL and comparing among period of time postoperatively. This study interested in small breed dogs using Chihuahua as model. The various breed conformation body weight and body condition score are the primary factors that affect the difference of joint movement pattern (Vilar et al., 2016). This thesis shows the standard joint angular motion in small breed dogs during trotting on treadmill. Agostinho et al. (2011) found difference of magnitude in stifle during trotting on treadmill among normal clinically Rottweilers and Labradors. The degree of AROM of stifle of Rottweiler (52.48±4.04 degree) was greater than Labrador (62.37±6.53 degree). This study provides the universal baseline data of linear angular motion and passive range of motion of hip, stifle and tarsal joint on sagittal plane of small breed dogs. The standard degree of AROM of hip joint, stifle joint and tarsal joint of Chihuahua were 18.81±1.56, 51.60±7.18 and 47.59±7.05 degrees respectively.

In present study, the kinematic parameter of the right and left hind limbs were not statistically difference. The Chihuahuas were observed at the trot gait, which is the symmetrical gait. In a 2D kinematic analysis using Labrador and Chihuahua at the trot, found that the linear joint angular displacement of one side is mirror the opposite side (Gillette and Zebas, 1999; Klinhom et al., 2015). Nevertheless, in a study using inverse dynamics analysis of gait, it was found that the dog has a mechanically dominant on the right side during the trot (Colborne, 2008).

The MPL affected stifle joint medial patellar luxaton causes shortening of extensor moment arm of quadriceps muscle then decreasing the force acting on the stifle joint and results in a smaller stifle extensor moment. This present study was focus on bilateral grade III MPL stifle. Klinhom et al. (2015) study the difference between normal, unilateral and bilateral patellar luxation in Chihuahua. They observed that the AROM of stifle joint of both group of patellar luxation were not significant different with normal group. But the AROM of the hip and the tarsal joints of patellar luxation group had decreased when comparing with the normal. In this study, we found that the degree of AROM of all three joint of hind limbs of bilateral grade III MPL dogs were significant different to normal dogs. The difference of kinematic system causes the difference of result.

Even the extensor performance of stifle is loss, the others two joint (hip joint and tarsal joint) will compensate the limb length discrepancy by increases the degree of motion to compensating for walk. The present study found that the MPL dog adapted the motion of hip joint and stifle joint to compensate the limb length discrepancy. The degree of AROM of stifle joint of MPL was significantly lower while the tarsal joint and hip joint were significantly higher than normal group. The tarsal joint was more extension and less flexion, and the hip joint was less flexion to gain more their AROM.

The aim of MPL surgical correction is to realign the quadriceps apparatus and to stabilize a patella into the normal anatomical position, restore the stifle extensor mechanism and promote the normal joint range of motion. As seen in our study, we found that degree of AROM of stifle joint had significantly increased along all period of follow up in a similar way with the MEA of stifle joint. The MEA was significant increased along all period of post-operatively but the MFA in not changed. The dogs that suffering from MPL and loss of motion of stifle joint can cause the discomfort to move the stifle joint, then the flexor muscle group which is the counterbalance with stifle extensor muscle group by increased the flexor performance (the pre-operatively MFA was more decreasing than normal) to compensate the losing AROM of stifle as observed in our study. Moreover, the rectus femoris is one of the quadriceps muscle. It originates at the ilium, thus crossing both the hip and knee joint along its course. This muscle is a two-jointed muscle allows for hip flexion and stifles extension. Towle et al. (2005) showed the quadriceps angle (Q-angle) was decreased after MPL surgical correction. Even the stifle motion is changed after surgery; the rectus femoris should change the degree of flexion of the hip joint also. The fluctuation of MFA and AROM of the hip joint at 2 – 4 week post-operatively showed the rectus femoris was adapting its function after realigned th quadriceps muscle group.

The result shows that the increasing of MEA of stifle joint was related with the increasing of AROM. These can assumes the quadriceps muscle is the importance role play as main action to control the movement of stifle joint, more than the flexor muscle group. Moreover, after surgery the degree of AROM and the MEA of MPL group were return to similar with normal group at 6 week and 8 week. These shows that the functional of MPL affected stifle was return to normal on 6 weeks after surgery. We found that the AROM of hip joint and tarsal joint were decreasingly along all period of post-operatively. This shows the evidence of length compensation of MPL affected limb using the hip and the tarsal joint motion were resolved.

The passive joint range of motion is differing between dog breed (Jaegger et al., 2002; Thomovsky et al., 2016). The variety of limb shape causes the variation of joint angle. The PROM baseline in large breed has been validated in Labrador retrievers (Jaegger et al., 2002). The universal table for normal joint angle values may not be applicable between dog breeds. Thus, there is a need for published range of motion measurements in a variety of dog breeds. The present study reported the baseline values of PROM of hip joint, stifle joint and tarsal joint of small breed dogs using Chihuahua as model. The standard PROM of hip joint, stifle joint and hip joint of Chihuahua breed were 110.88±2.29, 117.31±3.82 and 131.36±2.67, respectively. In this study found that the joint angle of the right and left sides were not statistically difference. It is likely that the joint angle of one side of limb is baseline of another side of limb.

The value of PROM when measured by goniometer was higher than the value of AROM from kinematic motion analysis. It can be explain by the difference of open kinematic and closed kinematic chain measurement. The joints, muscles, and other anatomical structures function differ in open chain (non-weight bearing) and closed chain (weight bearing) (Lattanza et al., 1988). The gait represents movement which combines both the swing phase (open kinematic chain) and stance phase (closed kinematic chain). The degree of stifle joint angle during gait was increasing up to maximal during initial of stance phase, which is a closed kinematic chain (Svoboda et al., 2016). The end of closed chains is fixed on the ground and any adjustment in the angle in one joint reciprocally results in altered angles in the other joint. On the other hand, the goniometry was performed by the dog was restrained in lateral recumbence and the uppermost limb, which is an open chain was measured. The joint angle can be adjusted without incurring any changes in other joints in measured. The degrees of MFA of all three joints which are measured by static (measured by goniometer) or dynamic (measured by kinematic motion analysis) joint movement were differences. This study found that the static MFA was 2-3 times lower than dynamic MFA.

In the same way of kinematic measurement, the PROM and MEA of stifle joint of MPL group were lower than normal because the malalignment of quadriceps extensor mechanism of MPL group. Kowaleski et al. (2012) explained that the bilateral patellar luxation results from developmental malalignment of the quadriceps extensor mechanism. The developmental medial patellar luxation is a consequence of complex bone conformation abnormalities affecting the overall alignment of the limb. The varus gait with internal torsion of the foot despite external torsion of the distal tibia can effected to the range of motion of tarsal joint. We found that the PROM of tarsal joint of MPL group was lower than normal due to the low performance of tarsal flexion. Moreover, even we flex the tarsal joint the femorotibial stress might effects the stifle pain so the MFA of tarsal joint may lower than it could be and the PROM of tarsal joint may not represent the true PROM.

The arthrofibrosis of the stifle joint has been one of the more studied joints as a result of its frequency of occurrence. Paulos et al. (1994) reviewed the infrapatellar contracture syndrome which reduced range of motion after stifle arthrotomy. McMahon et al. (1990) have noted that some irreversible damage occurs to articular cartilage of the patella with infrapatellar contracture. Scar tissues can cause structures around stifle to become contracted, restricting normal motion. Depending on the site of scarring, the joint range of motion; i.e. flexion, extension, or both, affected (Kim et al., 2004). In case of stifle joint, The PROM was significantly increased on 6 week post-operatively and MEA was significantly increased along period follow up. Nevertheless, the stifle joint was not return to normal motion on 8 weeks post-operatively. the rehabilitation should be done more than 8 week after surgery.

The consequent pain may lead to the cascade of quadriceps weakness. The lameness score and owner's questionnaire were evaluated in this study. These are the subjective evaluation. The lameness score of MPL group pre-operatively was mild, then increased to moderate lameness on 2 weeks post-operatively and decreased until normal on 6 week post-operatively. While the owners rated the normal on 4 week post-operatively this shows the bias error of subjective lameness score. This method usually occur the inter-observer variability (Gillette and Angle, 2008; Waxman et al., 2008; Miqueleto et al., 2013). The mild conditions may still remain undetected so the objective evaluation was recommended (Quinn et al., 2007).

In conclusion, the MPL surgical correction can prove the performance of dynamic joint movement of stifle joint on 6 weeks after surgery; however, it cannot completely restore the static joint movement in 8 week after surgery. Clinical relevance, this kinematic motion analysis will allow the detection of consistent abnormal kinematic parameters that will be useful in the development of objective outcome measures for dogs with medial patellar luxaton. Moreover, we can predict the recovering progression of hip, stifle and tarsal joints movement of dogs with medial patellar luxaton undergoing surgical correction.

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APPENDIX

**Table A1** The pairwise comparisons of maximal flexion angle and maximal extension angle of the hip joint during trotting on treadmill

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | 0.001 | 0.994 | 1.000 | 0.582 | MFA |
| 2 wk Post | - | | 0.485 | 1.000 | 1.000 | |
| 4 wk Post | - | - | | 0.001 | 0.001 | |
| 6 wk Post | - | - | - | | 0.001 | |
| 8 wk Post | - | - | - | - | | |
| | MEA = Within-Sub Test; p-value = 0.087 | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A2** The pairwise comparisons of maximal flexion angle and maximal extension angle of the stifle joint during trotting on treadmill

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | - | - | - | - | MFA Within-Sub Test P-value=0.236 |
| 2 wk Post | 0.001 | | - | - | - | |
| 4 wk Post | 0.173 | 1.000 | | - | - | |
| 6 wk Post | 0.048 | 0.545 | 0.001 | | - | |
| 8 wk Post | 0.007 | 0.063 | 0.001 | 0.001 | | |
| | MEA | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A3** The pairwise comparisons of maximal flexion angle and maximal extension angle of the tarsal joint during trotting on treadmill

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | 0.001 | 1.000 | 0.239 | 0.172 | MFA |
| 2 wk Post | 0.001 | | 1.000 | 1.000 | 0.854 | |
| 4 wk Post | 0.003 | 1.000 | | 0.001 | 0.001 | |
| 6 wk Post | 0.044 | 1.000 | 1.000 | | 1.000 | |
| 8 wk Post | 0.056 | 1.000 | 0.165 | 0.298 | | |
| | MEA | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A4** The pairwise comparisons of active range of motion of the hip joint and stifle joint during trotting on treadmill

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | 0.001 | 0.001 | 0.001 | 0.001 | AROM of the stifle joint |
| 2 wk Post | 0.163 | | 0.030 | 0.022 | 0.001 | |
| 4 wk Post | 1.000 | 0.713 | | 0.737 | 0.001 | |
| 6 wk Post | 0.099 | 0.282 | 0.001 | | 0.001 | |
| 8 wk Post | 0.006 | 0.015 | 0.001 | 0.001 | | |
| | AROM of the hip joint | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A5** The pairwise comparisons of active range of motion of the tarsal joint during trotting on treadmill

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post |
|---|---|---|---|---|---|
| Pre-opt | | | | | |
| 2 wk Post | 0.001 | | | | |
| 4 wk Post | 0.001 | 1.000 | | | |
| 6 wk Post | 0.001 | 0.058 | 0.181 | | |
| 8 wk Post | 0.001 | 0.484 | 1.000 | 0.001 | |
| | AROM of the tarsal joint | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A6** The pairwise comparisons of maximal flexion angle and maximal extension angle of the hip joint from goniometric evaluation

| **P-Value** | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | - | - | - | - | **MFA** Within-Sub Test P-value = 0.371 |
| 2 wk Post | 1.00 | | - | - | - | |
| 4 wk Post | 0.01 | 0.11 | | - | - | |
| 6 wk Post | 1.00 | 1.00 | 0.01 | | - | |
| 8 wk Post | 1.00 | 1.00 | 0.01 | 1.00 | | |
| | MEA | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A7** The pairwise comparisons of maximal flexion angle and maximal extension angle of the stifle joint from goniometric evaluation

| **P-Value** | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | - | - | - | - | **MFA** Within-Sub Test P-value = 0.404 |
| 2 wk Post | 1.000 | | - | - | - | |
| 4 wk Post | 0.259 | 1.000 | | - | - | |
| 6 wk Post | 0.018 | 0.002 | 0.001 | | - | |
| 8 wk Post | 0.009 | 0.024 | 0.001 | 1.000 | | |
| | MEA | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A8** The pairwise comparisons of maximal flexion angle and maximal extension angle of the tarsal joint from goniometric evaluation

| **P-Value** | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Pre-opt | | 0.002 | 1.000 | 1.000 | 1.000 | **MFA** |
| 2 wk Post | 0.012 | | 0.001 | 0.001 | 0.001 | |
| 4 wk Post | 0.281 | 0.001 | | 1.000 | 1.000 | |
| 6 wk Post | 1.000 | 0.001 | 0.046 | | 1.000 | |
| 8 wk Post | 1.000 | 0.014 | 1.000 | 1.000 | | |
| | MEA | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A9** The pairwise comparisons of passive range of motion of the hip joint and stifle joint from goniometric evaluation

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post | |
|---|---|---|---|---|---|---|
| Normal | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | PROM of the stifle joint |
| Pre-opt | | 1.000 | 0.095 | 0.001 | 0.092 | |
| 2 wk Post | - | | 1.000 | 0.001 | 0.011 | |
| 4 wk Post | - | - | | 0.001 | 0.001 | |
| 6 wk Post | - | - | - | | 1.000 | |
| 8 wk Post | - | - | - | - | | |
| | PROM of the hip joint; Within-SubnTest P-value =0.071 | | | | | |

* This table presents the results of the Bonferroni post hoc test

**Table A10** The pairwise comparisons of passive range of motion of the tarsal joint from goniometric evaluation

| P-Value | Pre-opt | 2 wk Post | 4 wk Post | 6 wk Post | 8 wk Post |
|---|---|---|---|---|---|
| Pre-opt | | | | | |
| 2 wk Post | 0.001 | | | | |
| 4 wk Post | 1.000 | 0.001 | | | |
| 6 wk Post | 0.001 | 1.000 | 0.001 | 1.000 | |
| 8 wk Post | 0.003 | 1.000 | 0.001 | 1.000 | 1.000 |
| | PROM of the tarsal joint | | | | |

* This table presents the results of the Bonferroni post hoc test

# VITA

Kannika Chayatup, was born on November 21, 1988 in Bangkok, Thailand. After graduating from high school in 2006, she started study Veterinary Medicine at Faculty of Veterinary Medicine, Chulalongkorn University, Bangkok, Thailand. She interested to research in surgical veterinary field. She completed this program in April, 2012 with her thesis entitled: “Minimal Invasive Plate Osteosynthesis (MIPO) Technique in Dog in Clinical Practice”. After obtaining her Bachelor degree of Doctor of veterinary medicine (D.V.M.), she spent a few years to working as a general practitioner at Suanluang animal hospital and Thonglor pet animal hospital before embarking to study the Master degree in course of Veterinary Surgery, Faculty of Veterinary Medicine, Chulalongkorn University In August, 2014. During her study she was able to obtain the scholarship from the graduate School, Chulalongkorn University to commemorate the 72nd anniversary of his Majesty King Bhumibala Aduladeja. Her thesis was supported by the 90th Anniversary of Chulalongkorn University, Rachadapisek Sompote Fund.