Key Points

- Normal patellar tracking is influenced by static and dynamic constraints.
- It is assumed that dynamic constraints assume greater relative importance in the face of static constraint pathology such as patellar erosion.
- Radiographic measurement of femoral varus is prone to over-estimation even when radiographs are closely scrutinized for proper limb positioning.
- The ideal “target” femoral varus conformation following corrective femoral osteotomy (CFO) is not known.

Functional Anatomy

The patella is an ossification in the tendon of insertion of the quadriceps muscle group. The convex articular surface of the patella articulates with the concave femoral trochlea, bounded medially and laterally by ridges (Fig 1). The patello-femoral articulation functions as a simple pulley to alter the direction of the quadriceps muscle pull to accomplish stifle extension.

The quadriceps group converges on the patella and continues as the patellar ligament to insert on the tibial tuberosity. Proper anatomic alignment of the quadriceps/patellar mechanism with the underlying skeleton fosters proper patellar tracking. The patella is surrounded by attachments of joint capsule, retinaculum and medial/lateral femoropatellar ligaments whose balanced tension helps maintain normal patellar position.

Mechanical Alignment Concept

Normal patellar stability is the result of both healthy static constraints (such as normal patellar and femoral conformation and balanced tension within the patello-femoral ligaments and joint capsule) and dynamic constraints (such as proper alignment of the quadriceps/patellar mechanism with the underlying skeleton). The mechanical alignment concept states that proper anatomic alignment of the quadriceps/patellar mechanism with the underlying skeleton promotes patellar stability. When the quadriceps muscle contracts, it seeks to form a straight line with the patella positioned between its origin and insertion. If the long axis of the quadriceps is not centered over the trochlear sulcus, there is an imbalance in muscular forces favoring patellar luxation (PL). Excessive femoral varus and external femoral torsion are commonly associated with medial patellar luxation (MPL). Distal femoral varus moves the long axis of the quadriceps muscle medial to the trochlear sulcus (Fig 2). This discrepancy causes a strong medially-directed force upon the patella.
force upon the patella during muscular contraction. The strength and length of the quadriceps muscle in large breed dogs amplifies this discrepancy as compared to small breeds of dogs. In instances of healthy static constraint, minor mal-alignment in the dynamic constraints may be tolerated without gross events of patellar luxation. However, when the static constraints are pathologic, either as a cause or effect of patellar luxation, the role of mal-alignment in the dynamic patello-femoral constraint is more critical. The alignment discrepancy between the quadriceps-patellar mechanism and the underlying skeleton has been measured as the quadriceps angle (Q-angle). To measure Q-angle, a line is drawn from the origin of the rectus femoris (immediately cranial to acetabulum) to the center of the femoral trochlea (Fig. 3). Next, a line is drawn from the center of the femoral trochlea to the tibial tuberosity. The Q angle is formed between these two lines. Medial displacement of the tibial tuberosity, regardless of cause, results in a medial Q-angle. The magnitude of the medial Q-angle has been correlated the severity of MPL, but a cause and effect relationship has not been established. For instance, MPL results in internal stifle rotation that subsequently causes an increased Q-angle. Conversely, medial displacement of the tibial tuberosity will increase the Q-angle and contribute to MPL. As a result of concerns that Q-angle may be influenced by skeletal conformation as well as rotational position of the stifle, more emphasis has been placed on measurement of femoral conformation. Corrective femoral osteotomy (CFO) has been effectively used to treat MPL complicated by “excessive” femoral varus.

Controversy #1 – Can we diagnose “excessive” femoral varus? (ie, when is CFO indicated?)

There is little controversy that excessive femoral varus contributes to MPL, but what constitutes “excessive”, and more specifically, indications for CFO are not clear. Development and use of a validated method of femoral varus measurement that can be applied to normal populations and MPL populations within a given breed will help answer these questions. Validation of femoral varus measurement, as with any diagnostic test, requires that the method be repeatable (within investigators), reproducible (between investigators), and accurate. Original work in the field concluded that measurements of femoral varus and torsion made from carefully positioned radiographs and CT scans were accurate, but the rigor of the statistical analysis and that fact that the imaging was performed on custom-mounted isolated pelvic specimens of normal dogs left some doubt regarding the accuracy of varus measurements in the clinical arena. Subsequent work in our laboratory showed radiographic measurement of canine femoral varus was repeatable and reproducible in normal Walker Hounds, but was not statistically accurate in predicting true anatomic varus. In that study, the range of femoral varus measurements in the normal cadavera was extremely small (approximately 7°) such that the statistical noise:signal ratio may have obscured a true relationship between radiographic femoral varus and true anatomic femoral varus. In a third study in which the studied femoral varus conformation ranged approximately 20°, our data indicate that radiographic measurement of femoral varus is prone to over-estimation of the actual anatomic varus. These data show that the best utility for radiographic measurement is as a “diagnostic screening tool” to identify patients without excessive anatomic varus because it has a high (96%) negative predictive value (if the
radiographic measurement says that the femur does not have excessive varus, you can be confident it is true), but a marginal (72%) positive predictive value (if the radiographic measurement says the femur has excessive varus, it may be a false reading and another means of verification is advised). It must be emphasized these data are from fresh canine cadavers that were properly positioned for radiographs and radiographs were closely scrutinized for acceptability. So, while it appears that we are making strides toward resolving controversy #1, we are not there yet. Once a validated method of femoral conformation measurement is established, comparing the conformation between “normal” and MPL populations within a breed should shed some light on the role of femoral conformation on the MPL. Studies investigating the role of femoral conformation upon patello-femoral mechanics will also be important and are ongoing in several research laboratories. Recent theoretical analysis based upon morphometric data demonstrates a significant medially-directed patello-femoral force in normal stifles of red foxes (limb morphology similar to domestic dog) that is influenced by Q-angle.

Controversy #2 – How is femoral varus best measured?

Femoral varus has been evaluated by measurement of either femoral varus angle (FVA) or anatomic lateral distal femoral angle (aLDFA). These methods are closely related and one is not likely to be any more accurate than the other. The current trend is toward adopting use of the aLDFA. Each method requires determination of the anatomic proximal femoral axis by drawing a line through center points of the proximal femoral diaphysis; these points are identified at one-third and one-half of the femoral length with the aLDFA method. Each method also requires determination of the axis of the distal articular margin of the femur on Cr-Cd radiographs (Fig. 4); with the aLDFA method this axis is termed the distal joint reference line and for the FVA method it is called transcondylar axis. The aLDFA is the angle formed between the anatomic femoral axis and the lateral end of the distal joint reference line. The aLDFA’s measured from radiographs of Labrador Retrievers, Golden Retrievers, German Shepherds and Rottweilers were reported as 97°, 97°, 94° and 98° respectively, but the accuracy of these values in predicting the true anatomic conformation was not a component of that study. Measurement of FVA involves drawing the distal femoral long axis as a line perpendicular to the transcondylar axis. FVA is measured as the angle between the anatomic femoral axis and the distal femoral long axis. Thus, FVA is essentially the a-LDFA minus 90°. The FVA in normal Walker Hounds ranged from 2.4-8.2° when measured directly from the harvested femora and from 2.7-9.6° when measured from radiographs. Others have measured a mean FVA of 7.4° from radiographs of a homogenous.

Fig 4 – Preoperative planning on radiograph shows aLDFA determined as the angle formed by the distal joint reference line (DJRL) and the anatomic proximal femoral axis (apFA). The ostectomy is centered at the CORA and the base of wedge (Y) is calculated from the angle of the desired wedge (*) and the measurement of the femoral diameter at the level of the ostectomy (X) using the formula Y = tan * (x).
population of normal dogs. Regardless of whether measuring FVA or a-LDFA, multiple properly positioned radiographs are advised to maximize accuracy of measurements because incomplete hip extension and/or external rotation of the hips commonly induce dramatic artifactual distal femoral varus measurement. Femoral torsion can be measured from an axial radiographic view, but the accuracy of that measurement has not been definitively validated.

Controversy #3 - When is CFO indicated and to what angle should we correct?

Most veterinary surgeons agree that when coexistent with MPL, excessive femoral varus should be corrected, however, an objective definition for “excessive” has not been established (see controversy #1). Based upon the studies reported above, CFO has been recommended when MPL is accompanied by femoral varus angle >12° (aLDFA >102°). Long-term follow-up evaluation (4+ years) of large breed dogs treated with CFO for combined femoral varus and MPL had predictable femoral osteotomy healing, patellar stabilization, and long-term improvement in 10 parameters of patient comfort and function. Unfortunately, this report is merely a case series that reports successful outcomes; without a control group of similar dogs treated without CFO it is possible that similar results could be achieved using traditional MPL surgical treatments.

When performing CFO for MPL complicated by excessive femoral varus, a laterally-based, closing-wedge ostectomy is performed in most instances (Fig. 4). The wedge excision is planned at the center of rotation of angulation (CORA) as determined from preoperative radiographs (Fig 4). The CORA is located at the intersection of the proximal femoral long axis with a line bisecting the distal femur. If the CORA is located within patello-femoral joint, the ostectomy is moved slightly proximal to the femoral trochlea. In order to properly locate the ostectomy at the CORA during surgery, it is helpful to measure the distance from several identifiable landmarks (lateral fabella, lateral trochlear ridge, etc) to the CORA on radiographs. FVA or aLDFA is measured from several acceptable radiographs. The angle of the ostectomized wedge is the difference between the measured angle and the desired postoperative angle. Currently, it is unknown as to whether the “target” postoperative femoral varus should be that of the contra-lateral limb (in dogs affected with unilateral MPL), or that of an acceptable “normal” reference value, or closer to zero femoral varus (FVA = 0°, a-LDFA = 90°). An improved understanding of the effects of femoral varus on patello-femoral joint force from ongoing studies in several laboratories should help answer this question. Once the desired angle of wedge excision is known, the length of wedge base is determined using either a graphical method in which the wedge is drawn directly on calibrated radiographs or trigonometric method (Fig 4) in which it is calculated from the intraoperative measurements of femoral diameter at the level of the ostectomy.

In the dorsally-recumbent patient, a lateral parapatellar arthrotomy is made to allow medial displacement of the quadriceps/patella mechanism. Femoral varus conformation is visually confirmed. The level of the proposed ostectomy level is marked as preplanned on the radiographs. A straight line is scored into the femur spanning the region of the planned osteotomy to serve as an alignment indicator. A jig properly positioned on the cranial femoral surface helps maintain alignment during plate application. The proximal jig pin is
placed within the anticipated span of the bone plate to reduce the risk of femoral fracture through the pin tract. Recently, an elegant jig that allows for scaled multi-planar angular adjustments has been introduced to the veterinary market (DRD deformity reduction device, Hofman SRL, Monza, Italy, www.hofmann.it). Contouring of the bone plate and temporary application to the distal segment with a single screw simplifies the procedure. The bone plate is then removed. In most instances, the CORA (thus the ostectomy also) is within ~ 2cm proximal to the lateral fabella. The wedge ostectomy is completed and the distal femoral segment is rotated about the distal jig pin into reduction. The femoral alignment is visualized by looking down its long axis. The previously etched line is used for reference in visualizing the varus correction and maintaining torsional alignment. Torsional manipulations can be made at this point if necessary. Kirschner wires can be temporarily implanted to maintain reduction of the osteotomy during bone plate application. The bone plate is re-contoured to adapt to the newly aligned femur and is applied to the lateral surface. Purpose-specific plates (DFO plate, New Generation Devices, Glen Rock, New Jersey, USA, www.newgenerationdevices.com; Fixin Femur plates, TraumaVet, Rivoli, Italy, www.traumavet.it; Femur plate, Jorgensen Laboratories, Loveland, CO, www.jorvet.com) and plates that can be contoured in multiple planes (SOP plate, OrthoMed North America, Vero Beach, FL) conform nicely to the natural procurvatum of the canine femur (Fig 6). Caution should be used, however, to avoid inadvertent damage to the cruciate ligaments as drills, taps and screws are directed in the region of the femoral intercondylar notch. The jig is removed. Varus correction is confirmed visually. Surgical treatments at the level of the stifle such as trochleoplasty, tibial crest transposition, medial soft tissue release and lateral imbrication are performed as indicated based upon the patient’s pathology. CFO is typically delayed until skeletal maturity to avoid distal femoral physeal damage and/or stress concentration created by the distal end of the plate near the distal femoral physis. This stress concentration effect combined with physeal weakening by the trochleoplasty may contribute to distal femoral physeal fracture in the early postoperative period. When femoral osteotomy is performed in immature pets, dynamic pinning can be added to the plate fixation to prevent physeal fracture.

Controversy #4 – What is the significance of altered limb loading induced by CFO?

The normal mean mechanical axis deviation (MAD) of the canine stifle and tarsus have been reported as medial 3.6% and medial 1.2%, respectively. An increased medial stifle- and tarsal-MAD is assumed in cases of isolated femoral varus. In such cases, CFO would be assumed to correct or improve the increased MAD. However, concurrent frontal plane deformity of the tibia would also influence the MAD. To date, little attention has been paid to stifle- and tarsal-MAD in pre-operative planning in small animal patients, but has been studied in humans.
References


