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DYSPLASIA OF *TROCHLEA FEMORIS* IN DOGS

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ABSTRACT

This article provides a comprehensive analysis of *dysplasia trochlea* in dogs, summarizing the most recent findings in the field and highlighting important new findings, as well as, areas that require further research. The anatomy of the knee and the *trochlea femoris*, as well as its function in maintaining knee joint stability, are covered in the first section. The accurate diagnosis of orthopaedic disorders, and injuries are necessary for efficient treatment, and this is made possible by understanding the anatomy of the knee. The factors that can affect the onset, development, and course of the disease are included in the section that follows, which discusses the etiology, and pathophysiology. Veterinary surgeons must measure trochlear femur dysplasia in dogs in order to determine the severity of the condition and the best course of treatment. It is typically assessed by looking at X-ray images and assigning a score, however, this can differ from one individual to another. New measurement techniques that give a better level of objectivity and precision, like CT scans or MRIs, are now being tested.

Key words: dog; dysplasia; orthopaedics; *trochlea femoris*

INTRODUCTION

The knee joint is a complex synovial joint with condyloid femorotibial, femoropatellar, and proximal tibiofibular articulations [7, 14, 46]. The changing any of the joint's anatomical components might cause dysfunction and damage to other structures [7]. Osseous, fibrocartilaginous, and ligamentous tissues make up the dog's knee joint, which often causes lameness [32]. The quadriceps, patella, trochlear groove, patellar ligament, and tibial tuberosity make up the knee extensor mechanism. Any variation in this arrangement of structures might produce anatomical changes in the distal femur and proximal tibia during growth, resulting in patellar instability [11].

The femoropatellar joint, formed by the asymmetrically shaped articular surface of the patella, and the femoral trochlear groove, is an incongruent joint that is often impacted by painful, and disabling degenerative processes like osteoarthritis. Incongruent joints, which trade stability for a range of motion, often develop pathogenic processes [9].

Dogs with trochlear dysplasia have shallow femur grooves, causing patella dislocation. This syndrome may be induced by persistent instability and lateral tracking, birth, or a combination of causes [2]. Patellar luxation severity affects symptoms. These include hindlimb lameness, structural anomalies such as femur or tibia bending, discomfort, and reluctance to move [47]. Medial patellar luxation affected 73 % and lateral luxation 27 % of large breed dogs [3]. The condition known as medial patellar luxation (MPL) exerts strain on the cranial cruciate ligament (CCL), resulting in its degeneration and subsequent rupture. The development of secondary osteoarthritis (OA) can be attributed to the presence of MPL [1].

MATERIALS AND METHODS

A thorough literature review was performed to fully investigate trochlear dysplasia in dogs. Electronic databases such as PubMed, Web of Science, and Google Scholar were exhaustively searched for the most recent publications. The search terms encompassed „trochlear dysplasia in dogs“, „patellar groove dysplasia“, „patellar luxation“, „patellar instability“, „patellofemoral instability“, and different combinations of these terms. After the search, we selected studies that were directly relevant to trochlear dysplasia in dogs. This research looked into trochlear dysplasia's causes, progression, diagnostic techniques, clinical presentation, available treatments, and results. Titles and abstracts were screened, and then papers with potential relevance were evaluated in full text. The chosen studies that fulfilled the objectives of this evaluation were used to gather data.

Anatomical features of the *trochlea femoris* and its role in patellar stability

Femoris muscle and patellar tendon complexes include the largest sesamoid bone, the patella. It acts as a biomechanical lever, increasing the quadriceps force during knee extension. Additionally, it centralizes the quadriceps muscle's divergent forces and transfers the tension around the femur to the patellar tendon. The complicated patellofemoral joint, where the patella meets the femoral trochlea, can become unstable [44, 45].

The intercondylar notch of the patellofemoral joint extends into the trochlea. The functionality of the extensor mechanism and the stability of the patellofemoral joint depend on the shape of the trochlear sulcus. Trochlear dysplasia, also known as a shallow sulcus, can result in diminished angle and depth of the groove, a small medial facet, and anterior knee pain [4, 24].

The bone contour and cartilage depth determine the concave shape of the trochlea [49, 53, 55]. The depth and angle of the trochlear fossa on the femur are important factors that provide valuable insights because they affect the stability of the patella in the trochlear fossa. The deepest point of the trochlear groove is midway between the proximal face of the lateral ridge and 50 % of the sagittal length of the femoral trochlea in a healthy dog's knee joint. The patella is thickest in the distal half and less than half the depth of the trochlear groove. The patella's midsagittal connection to the trochlear groove is particularly evident [38]. Pettazzoni [42] measured the patellar bone's maximal craniocaudal thickness and trochlear groove depth using three-dimensional multiplanar reconstructive computed tomography. The mean maximum trochlear groove depth was 46 % of the patellar thickness [42]. Trochlear dysplasia has a significant impact on patellofemoral kinematics, contact pressure, contact area, and stability and appears in a variety of geometric configurations [54].

Etiology and pathogenesis

A survey of the literature in the field of human medicine revealed that most cases of dysplasia arise due to abnormal forces acting on the patellofemoral joint [21]. According to a study conducted on rabbits, inappropriate patellar positioning can cause excessive flattening of the distal femoral groove, which can increase the risk of patellar instability [20]. A study by L i et al. investigated the effect of patellofemoral instability on trochlear groove development in growing rabbits. Their research found that the pattern of patellar dislocation in young rabbits can cause dysplasia in the femoral trochlea. If patellar dislocation is present, it can affect the normal function of the quadriceps mechanism, leading to secondary bone changes [31].

The absence of physiological pressure of the patella on the articular cartilage of the trochlear groove during growth in dogs can prevent the development of a sufficiently deep and wide groove, which is known as trochlear hypoplasia [11]. This was confirmed in a study conducted on growing rats. It was confirmed that surgical removal of the patella and dislocation of the patella in growing rats can lead to a dysplastic trochlear groove. Along with changes in the bony structure of the trochlear groove, early remodelling of both the articular cartilage and the underlying subchondral trabeculae occurs postoperatively. Therefore, inadequate loading of the patellar bone after birth may affect the morphological development of the *trochlea femoris* [58].

Recent research has shown the association between certain anatomical traits and patellar luxation in dog breeds. Garnoeva found in 2022 that tiny female dogs of particular breeds are more prone to medial patellar luxation due to anatomical factors. A lower patellar thickness and shorter medial femoral condyle allow the kneecap to leave the trochlear groove [16]. Pugs, French Bulldogs, and English Bulldogs without clinical patella luxation were examined for trochlear sulcus depth by Matchwick et al. [33]. A validated computed tomography ratio of maximum trochlear sulcus depth and maximum craniocaudal patella thickness was used. The study discovered that French and English Bulldogs had shallower trochlear sulcuses than Pugs, suggesting that breed-specific traits may affect them [33].

Longo et al. found that dogs with medial patellar luxation exhibited a different femoral trochlear groove angle. Small breeds had a shallower femoral trochlear groove angle than medium/large breeds [30].

Femoral rotational osteotomy with anteversion increased trochlear dysplasia in a new approach. Image analysis confirmed that trochlear shape greatly influences femoral anteversion. Femoral anteversion flattens and dysplasticizes the trochlea. Trochlear dysplasia flattens the femoral groove, yet this investigation discovered a boss in the anterior proximal trochlea. This boss will prevent the patella from smoothly engaging into the groove when the knee is flexed [20, 21, 22, 29, 57].

Trochlear dysplasia research has advanced. Tang et al. revealed that patellar hypermobility and dislocation produce trochlear dysplasia, which worsens with age. The study indicated that inadequate or excessive loading can cause trochlear dysplasia [51]. Recently, an abnormality of the trochlear bone with preterm birth and obstetric presentation in rats has been detected. The obstetric presentation can cause trochlear abnormalities in neonatal knees. Trochlear dysplasia risk increases as the foetus stays *in utero* [28].

Clinical signs and diagnostics

Up to 85 % of patients with symptomatic patellar instability had trochlear dysplasia, which Brattström [5] and Dejour [10] identified as a major contributor to repeated patella subluxation.

The forces required for subluxation or dislocation can be influenced by the depth and angle of the slopes on the articular facets on either side [20].

According to Powers [43], patients with patellofemoral discomfort often have a smaller groove, and people who feel pain beyond 27 degrees of flexion show a considerable loss in groove depth. Significant research has been conducted on the distal femoral sulcus angle – a prominent landmark in the trochlear groove. A recent MRI study found that people with patellar instability have a less curved distal trochlear groove compared to people without pain [13, 20]. Furthermore, according to Hodel et al., high-degree patellofemoral dysplasia in humans commonly coexists with frontal and axial leg misalignment [19]. The evaluation of abnormal trochlear development in small dogs can involve three stages of classification, with indications of mild and moderate trochlear dysplasia including a shallow trochlear groove and hypoplasia of the medial femoral condyle [15].

Higher sulcus angle values, as well as noticeably lower levels of trochlear depth, medial trochlear inclination, and the ratio of patellar thickness to trochlear depth, were indicators of changes in the depth and form of the trochlea [15].

The potential effects of patellar dislocation in growing rabbits are clarified by a recent study by Dai et al. [8]. It showed that this condition can result in severe subchondral bone loss and trochlear dysplasia, underscoring the significance of appropriate care and therapy. Furthermore, it was discovered that the cartilage degenerative alterations brought on by patellar dislocation will get worse with time. The expression of MMP-13, an enzyme that breaks down cartilage, increased whereas TRPV4 and collagen II, which are crucial for maintaining healthy cartilage, were expressed less. These results are in line with earlier studies implying that improper patellofemoral joint biomechanics and added strain can cause cartilage degradation [20]. In order to avoid long-term problems including trochlear dysplasia and cartilage degeneration, it emphasizes the significance of early diagnosis and adequate care of patellar dislocations.

Imaging techniques that can be used to diagnose trochlear dysplasia of the femur in dogs

A complex system of osseous, articular, fibrocartilaginous, and ligamentous components make up the stifle joint. However, accurate diagnostic imaging is challenging to achieve due to its constrained joint space, complex composition, and tiny component structures. Furthermore, the overlap between several tissue types can make it difficult to make a diagnosis using just one imaging modality [32]. With the help of lateral radiography views [35], skyline radiographic views [34], and CT images [52], trochlear depth assessment has been established. The use of sedation or anaesthetic may even be necessary with these techniques due to the need for proper placement. Planning surgical operations for people with reoccurring patellar instability and trochlear dysplasia can be made easier with a greater understanding of imaging techniques and the production of 3D models of patellofemoral joints affected by dysplasia [26].

Radiological evaluations are regarded as a crucial component of the treatment of patellar instability. However, assessments of patellar instability are affected by the knee posture, which cannot always be consistent between examinations [59]. The distal, middle, and proximal trochlear grooves cannot be distinguished in the skyline view, which can only provide a 2D evaluation of the 3D structure. Therefore, it might not provide a reliable and consistent measurement of the trochlear groove's depth and angle [20]. In contrast, Garnoeva claimed that tangential X-ray images of the canine stifle joints can sufficiently evaluate the groove's depth and shape [15].

In dogs, adding ultrasonography to clinical and radiographic exams can help with stifle joint disease diagnosis. Sonography can give a view of the soft tissue components of the joint whereas radiography can evaluate the bony components of the joint and their interactions [25]. When performing joint imaging, sound waves move more slowly through joint fluid and more quickly through bone. Ultrasonography is therefore particularly useful for examining soft tissue features in the stifle joint. This method is efficient for finding arthropathies, neoplasia, meniscal anomalies, cartilage, muscles, tendons, and ligaments. In a recent study, ultrasonography was found to be a reliable technique for determining the trochlear groove's depth and evaluating the femoral groove [36].

A standardized approach for precisely measuring the femoral trochlear groove using CT has been developed [30, 38, 42] The femoral trochlea can be evaluated in 3D using CT scanning, which has the benefit of allowing precise point identification when measuring [38]. The ability to manipulate 3D reconstructed pictures provided by CT scanning also makes it easier to identify specific points of interest [38, 39].

In general, radiography, CT scans, and MRI scans can all be used to evaluate the sulcus angle accurately, but only CT and MRI scans can be used to precisely measure the trochlear depth [48]. The Insall-Salvati (IS) ratio was the sole measurement used for CR, CT, and MRI that showed strong consistency and agreement between various observers as well as within the same observer [56].

Approaches for assessing femoral trochlear dysplasia

The trochlear dysplasia of the femur can be evaluated using a variety of techniques, such as:

1. Dejour system of classification: According to the Dejour categorization system, dysplasia can be divided into four types: Type A, Type B, Type C, and Type D (Table 1) [23]. It has been determined that Dejour's evaluation of trochlear depth is an important diagnostic tool for trochlear dysplasia and for estimating the possibility of future patella dislocation because it was the sole measurement judged pertinent for this use [41]. This measurement helps predict future risks of patellofemoral discomfort. The lateral inclination of the trochlea has emerged as a nearly perfect form of dependable measurement approach and may serve as a new benchmark for quantifying trochlear dysplasia in contrast to Dejour's method, which is unreliable [40].

2. The Insall-Salvati index: This index is calculated by dividing the maximum length of the patella – measured from the lowermost point to the uppermost point of the patella – by the length of the patellar tendon, which is measured from the lowermost point of the patella to the tibial tuberosity [56]. The Insall-Salvati ratio has drawbacks despite being a helpful tool. One of these restrictions is the ratio's insensitivity to the patella's morphology. The Insall-Salvati ratio can have misleading values because of the abnormal patella [17].

3. Caton-Deschamps index: This ratio is calculated by dividing the distance between the lowermost portion of the patellar articular surface and the anterosuperior point of the tibial plateau by the length of the patellar articular surface [56].

4. Tuberositas tibae and trochlear groove (TT-TG) distance: According to Hingelbaum et al., the TT-TG

Table 1. Imaging characteristics of the various forms of trochlear dysplasia according to the Dejour classification [23].

Dejour type	Lateral radiograph	Axial image
Type A	Crossing sign	Shallow trochlea or symmetric concave trochlea
Type B	Crossing sign and supratrochlear spur	Flat or convex trochlea
Type C	Crossing sign and double contour	Asymmetry of the trochlea faces; lateral facet convex with hypoplastic medial facet
Type D	Crossing sign, supratrochlear spur, and double contour	Asymmetry of the trochlea faces; vertical slope demonstrating a "cliff" pattern

distance is increased between the tuberositas tibae and the trochlear groove [18]. The increasing TT-TG distance, or the distance between the tibial tubercle and the trochlear groove, is one of the main factors that raises the risk of patellofemoral instability. The externalization of the tibial tubercle and the medialization of the trochlear sulcus in trochlear dysplasia instances serve as objective indicators of the extensor mechanism's dysfunction [12, 37].

5. Sulcus angle: The measurement of the femoral trochlear groove's angle can be used to gauge the groove's depth before surgery and determine whether a deepening of the groove is required [30]. The surface area measurements for the articular cartilage and the subchondral bone contour have been shown to differ in the field of human medicine [36; 50].

6. Trochlear depth: The depth of the trochlear groove is a key factor in ensuring that the patella is stable over the front of the knee [20].

The sulcus angle, trochlear depth, and Dejour's classification are the metrics that have received the most attention [48]. Analysing these characteristics before surgery can enhance surgical planning and decision-making [15].

Methods of measuring trochlear dysplasia of the femur

Several measurements have been developed and presented to describe trochlear dysplasia, but experts cannot agree on which measurements should be used to diagnose the condition or choose the best course of action [41].

The sulcus angle, anterior and posterior condylar angles, and the heights of the medial and lateral femoral condyles are some of the factors that define the morphology of the trochlear anatomy. Measuring several morphometric parameters is required for the radiographic assessment of trochlear morphology in dogs. According to a study by Garnoeva [15], five of these indicators are significant for the identification of canine trochlear dysplasia. There were measured six morphometric factors to look into how trochlear dysplasia develops in dogs. The trochlear sulcus angle (SA), lateral and medial trochlear inclination angles (LTI; MTI), trochlear groove depth (TD), patella thickness (PaT), and the ratio of trochlear groove depth to patella thickness (PaT/TD) are among the measurements that are comparable to those employed in human medicine [15].

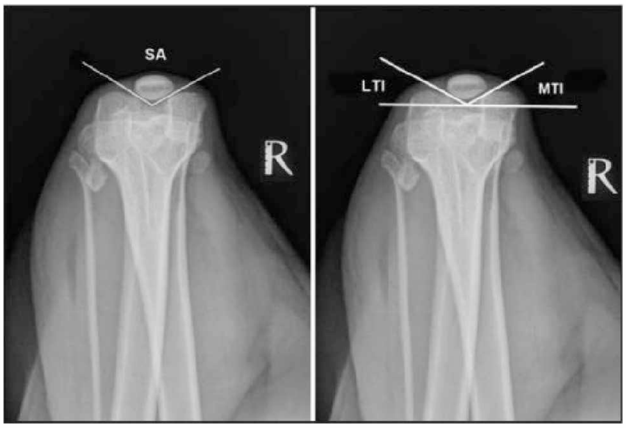

Fig. 1. Measurement of trochlear sulcus angle (SA) on the left and measurement of lateral and medial trochlear inclination (LTI; MTI) on the right [15].

Fig. 2. Measurement of trochlear depth (TD) on the left and measurement of patellar thickness on the right [15].

In a study by Mochizuki and Honnami [36], six characteristics were assessed on typical transverse scans of the femur (Figure 3). In the transverse pictures, a baseline was created perpendicular to the caudal condyles as a point of reference. The angles between the facet inclination and the baseline were used to measure the medial trochlear slope (MTS) and lateral trochlear slope (LTS).

The distance between the most cranial points of the medial and lateral trochlear ridges and the most caudal point of the femoral trochlea was used to calculate the medial trochlear ridge height (MRH) and lateral trochlear ridge height (LRH). The distance between the intercondylar fossa and the most caudal point of the femoral trochlea was used to calculate the height of the middle portion of the femoral trochlea (HMF). The distance between the intercondylar fossa and the baseline measured the height of the caudal section of the femoral trochlea (HCF) [36].

For each section of the measured groove, Carneiro et al. [6] discovered a substantial difference in the outcomes. This shows that the trochlear groove measurements should be tailored to the dog's breed and that it's crucial to standardize the values and narrow the range of variance.

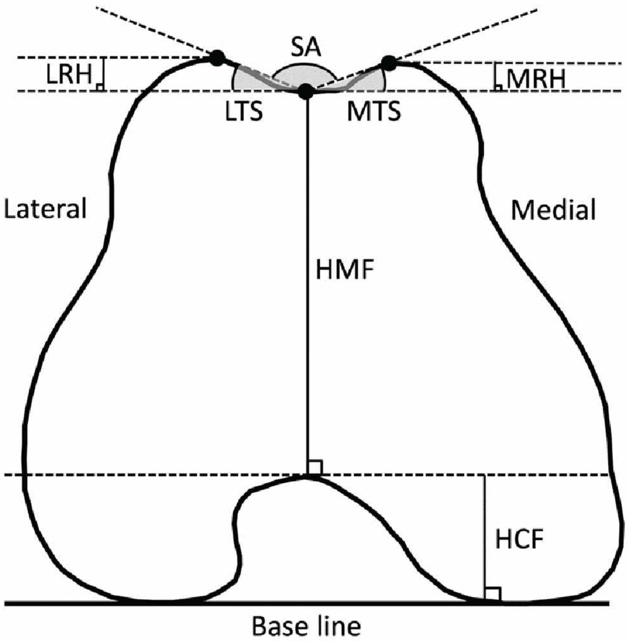

Fig. 3. Transverse image of the femur with six parameters [36].

CONCLUSIONS

In this article, we analysed the results of several research that focused on trochlear dysplasia in dogs. Our goal was to gain a better understanding of the problem as well as the best ways to treat it in canine patients. Following a comprehensive review of the relevant published material, we have uncovered numerous important concepts that are associated with trochlear dysplasia. It appears that a combination of genetics and environmental variables is to blame, but we need further research to fully understand how this process works. Dogs that have trochlear dysplasia are more likely to suffer from patellar luxation since the condition is caused by abnormalities in the groove of the trochlea. In summing up, this analysis drives home the point that early diagnosis and treatment of trochlear dysplasia in dogs is extremely important. Veterinarians, breeders, and dog owners must work together to reduce the occurrence of this orthopaedic disorder in canine populations and the impact it has on these populations. This study provides new information that adds to what is already known about trochlear dysplasia in dogs and stresses the need for additional research as well as careful monitoring to enhance the health of dogs that are affected by the condition.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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