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A radiographic study on correlation between Distraction Index with various stifle joint parameters in Canine Hip Dysplasia

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Canine hip dysplasia (CHD) is a common orthopaedic condition in dogs, marked by increased joint laxity. This leads to a change in force distribution on the hip joint during growth, affecting limb alignment. Anatomical deformities like coxa valga or varus and genu valgum or varum increase the risk of medial patellar luxation and other stifle affections. In the present study, the angular alterations in the femur and tibia were compared and their correlation with the severity of CHD was evaluated. Statistical analysis of the data obtained from radiographic evaluation revealed that proximal femoral angular alterations showed no significant variation and correlation with distraction index (DI), except Norberg angle, while distal femoral angular alterations (femoral varus angle and quadriceps angle) were significant with severity of CHD, exhibiting a strong positive correlation with DI. Advancing CHD worsens the distal femur varus deformity, affecting the quadriceps extension mechanism and increasing susceptibility to stifle affections. Proximal tibia angles (tibial plateau angle, proximal tibial axis angle, and mechanical medial proximal tibial angle) had a statistically significant positive correlation with DI. Thus it can be inferred that dogs with CHD may develop anatomical alterations in distal femur and proximal tibia, potentially predisposing them to patella luxation and cranial cruciate ligament rupture.

Key words: *Canine hip dysplasia, Distraction index, Femoral angles, Tibial angles, Angular deformities.*

Canine hip dysplasia (CHD) is a prevalent orthopaedic condition in dogs, characterised by increased laxity in the hip joint. This laxity disrupts the normal gait, this altered gait may affect the overall mechanics of the joint (Lust, 1997). Changes in hip joint mechanics often lead to deformities such as coxa valga or varus, with coxa varus specifically causing laxity in the extensor mechanism (Bound *et al*., 2009). The laxity in the quadriceps complex mechanism can lead to patellar instability, skeletal changes such as distal femoral varus or valgus, external or internal torsion of the distal femur, proximal tibial varus or valgus, and internal or external tibial torsion, as well as a shallow trochlear sulcus and abnormal stress on the stifle joint and the cranial cruciate ligament (CCL), and may contribute to cranial cruciate ligament rupture (CrCLR) (Marsolais *et al*., 2002). The existing literature has not thoroughly explored how dysplastic changes in the hip can impact the stifle, potentially predisposing it to stifle-related issues. Therefore, this study focused on the radiographic assessment of angular deformities of stifle joints in dogs affected by CHD and to find out correlations between CHD and the angles of the femur and tibia if any.

Materials and Methods

Selection and grouping of animals

Dogs presented with a history of hind limb lameness were screened and those with hip dysplasia were selected for study. Out of total animals screened, 40 dogs with a distraction index (DI) ranging from 0.001 to 1.600 were selected for the study, irrespective of their sex, weight and age. Informed consents were obtained from the owners of the animals selected. Selected dogs were randomly allotted into four groups as represented in table 1.

Table 1: Grouping the dogs based on the distraction index

Groups	Distraction index
Group I	Below 0.300
Group II	0.300 to 0.500
Group III	0.500 to 0.700
Group IV	above 0.700

Radiographic evaluation

In all the dogs radiographs of the hip and stifle joints were obtained under general anaesthesia with inj. xylazine HCl (0.25-0.5 mg/kg body wt), inj. butorphanol HCl (0.2 mg/kg body wt), inj. midazolam (0.2 mg/kg body wt) and inj. ketamine HCl (2-5 mg/kg body wt). The route of administration was selected based on the temperament of the animal. Radiographs of the femur including the coxofemoral joint were taken in ventrodorsal extended (Ginja *et al*., 2010) and distracted views (Ulfelder *et al*., 2019; Seesma, 2022). The tibia including the stifle joint was subjected to craniocaudal, mediolateral and skyline radiographic projections (Paley, 2002; Osmond *et al*., 2006; Glassman *et al*., 2011). Digitalised radiographs were generated using image suite V4 software and evaluated using specialized measurement tools.

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Angular measurements

The severity of CHD was graded based on the DI (Rungee *et al*., 2010), which was calculated from distracted hip joint radiographic views following the method recommended by Ulfelder *et al*. (2019) and Seesma (2022) (Fig. 2A). The Norberg angle (NA) was measured from extended ventrodorsal radiographic projections as described by Comhaire and Schoonjans (2011) and Verhoeven *et al*. (2012) (Fig. 2B). Angle of inclination (AOI) was measured on the radiograph from ventrodorsal extended radiographic projection using Symax method developed by Rumph and Hathcock (1990) (Fig. 1A). The measurements of the anatomic lateral proximal femoral angle (aLPFA), anatomic lateral distal femoral angle (aLDFA), mechanical lateral proximal femoral angle (mLPFA), and mechanical lateral distal femoral angle (mLDFA) were made on radiographs taken in the frontal plane of the femur following the method developed by Tomlinson *et al*. (2007) (Fig. 1B).The femoral varus angle (FVA) was also measured on radiographs as described by Dudley *et al*. (2006) (Fig. 1D). The quadriceps angle (QA) was measured on radiographs as outlined by Pinna and Romagnoli (2017) (Fig. 1E).

The tibial plateau angle (TPA), mechanical cranial proximal tibial angle (mCrPTA), mechanical caudal proximal tibial angle (mCdPTA), mechanical cranial distal tibial angle (mCrDTA), mechanical caudal distal tibial angle (mCdDTA), and the proximal tibial axis angle (PTA) were recorded through measurements obtained from radiographs in the sagittal orientation of the tibia (Paley, 2002; Reif and Probst, 2003; Reif *et al*., 2004; Osmond *et al*., 2006; Glassman *et al*., 2011 and Guenego *et al*., 2017) (Fig. 3 B, C & D). The mechanical medial proximal tibial angle (mMPTA) and mechanical medial distal tibial angle (mMDTA) were measured on radiographs in the caudocranial view of the tibia as described by Dismukes *et al*. (2007) (Fig. 3A).

Trochlear wedge angle (TWA) and trochlear wedge depth (TWD) were measured from the skyline radiographic projection of stifle joint (Boonchaikitanan *et al*., 2019; Garnoeva, 2021) (Fig. 2C & D). Patellar ligament to patella length ratio was measured from mediolateral view of stifle joint (Johnson *et al*., 2006) (Fig. 3E).

Serum biochemistry

Blood samples were collected for estimation of

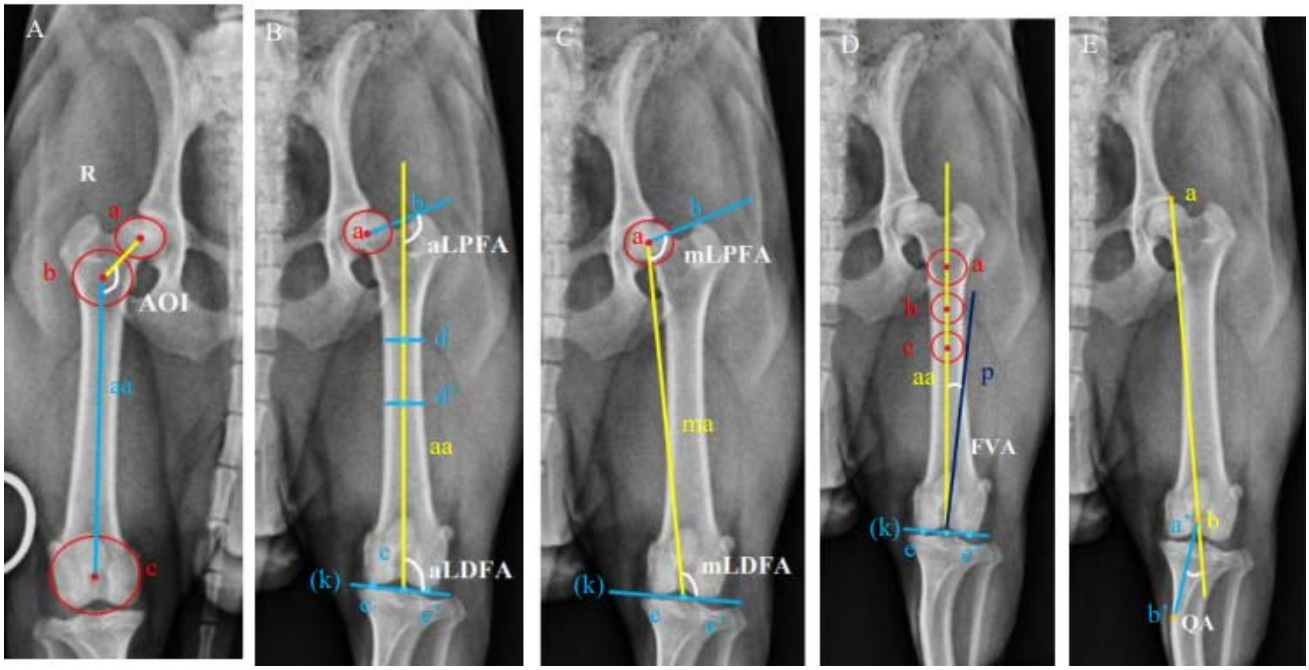

Fig. 1: Angular measurement techniques. (A) Angle of inclination (AOI) with the SYMAX method. Point a: centre of the head of the femur; point b: centre of the circle in the proximal metaphysis of the femur; point c: centre of the circle in the distal metaphysis of the femur; aa: anatomic axis. (B) Anatomic lateral proximal femoral angle (aLPFA) and anatomic lateral distal femoral angle (aLDFA). Point a: centre of the head of the femur; point b: proximal tip of the greater trochanter; point d: midpoint of 1/2 of the length of the femur; point d': midpoint of proximal 1/3 of the length of the femur, points e and e': most distal convexities of the femoral condyles; (k): distal joint orientation line; aa: anatomic axis. (C) Mechanical lateral proximal femoral angle (mLPFA) and mechanical lateral distal femoral angle (mLDFA). Point a: centre of the head of the femur; point b: proximal tip of the greater trochanter; points e and e': most distal convexities of the femoral condyles; (k): distal joint orientation line; ma: mechanical axis. (D) Femoral varus angle (FVA). Point a: midpoint of the femur at the level of lesser trochanter; point c: midpoint of the femur at its isthmus; point b: midpoint of the femur between point a and c; points e and e': most distal convexities of the femoral condyles; (k): distal joint orientation line; aa: anatomic axis; line p: line drawn perpendicular to the distal joint orientation line.(E) Quadriceps angle: Point a: lateral most point of acetabular rim; Point b and a': midpoint at intercondylar fossa; Point b': proximal point of tibial tuberosity.

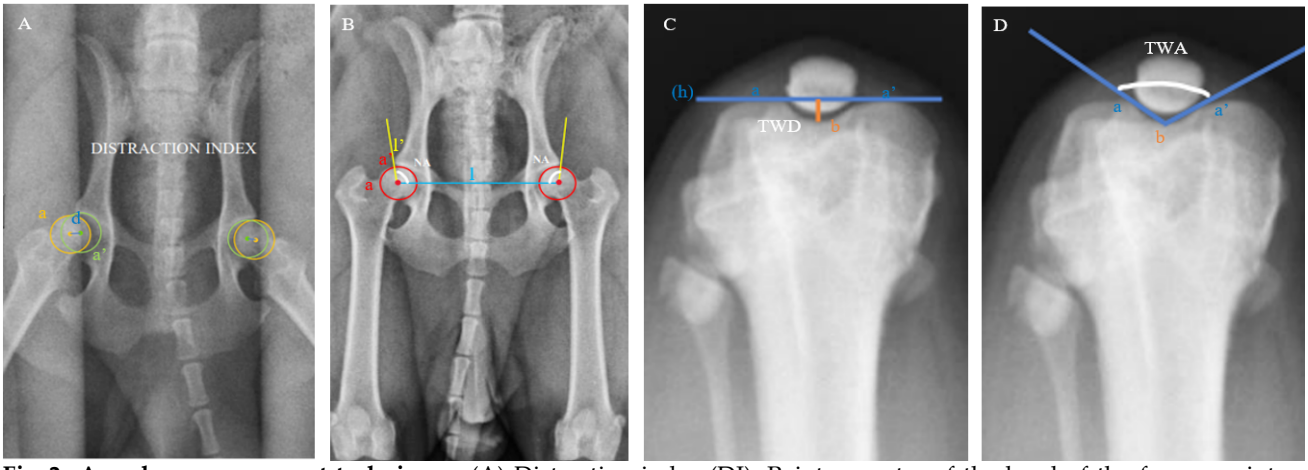

Fig. 2: Angular measurement techniques. (A) Distraction index (DI). Point a: centre of the head of the femur; point a: centre of the circle of acetabualar cavity; d is the distracted distance between points a and b. (B) Norberg angle (NA). Point a: centre of the head of the femur; point a':craniolateral lip of acetabulum; l: line connecting the centres of femoral heads; l': line connecting the centre of femoral head and ipsilateral lateral most point of acetabular rim. (C) Trochlear wegde depth (TWD): (h) horizontal line connecting the proximal most points of medial (a') and lateral (a) condyles of femur. Line b: measures the depth by connecting horizontal line with deepest point of the trochlea; (D) trochlear wedge angle (TWA) point a' and a: line connecting the proximal point of femoral condyles to deepest point of trochela.

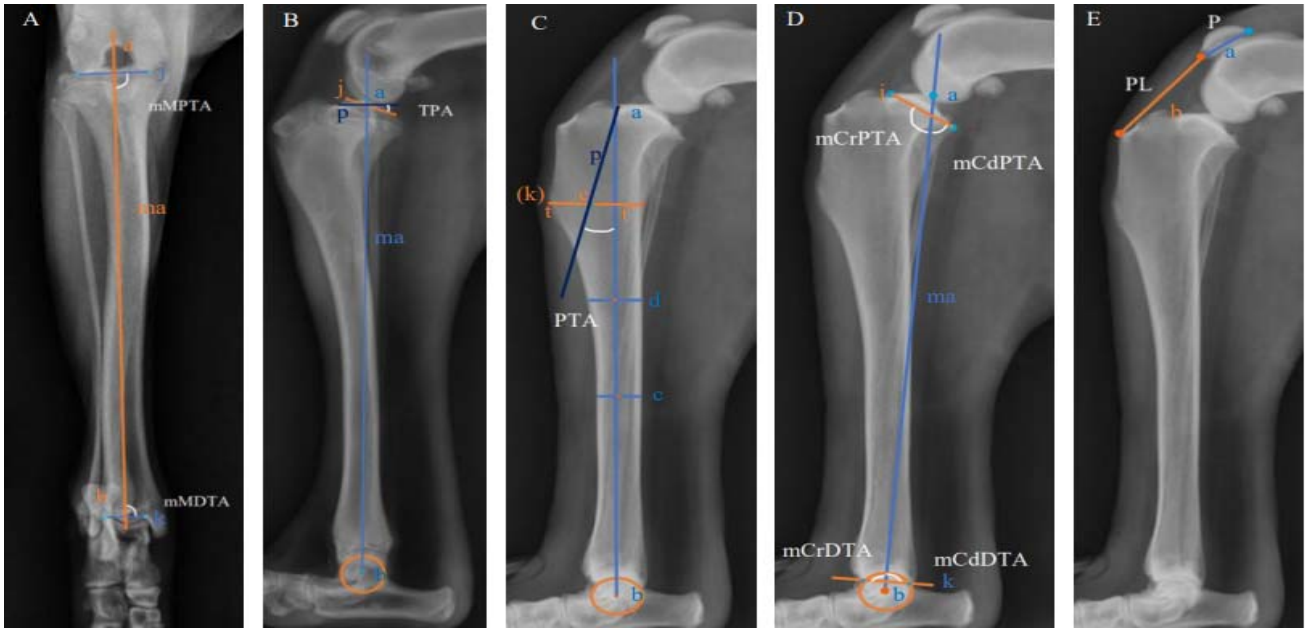

Fig. 3: Angular measurement techniques. (A) Mechanical medial proximal tibial angle (mMPTA) and mechanical medial distal tibial angle (mMDTA). Point a: centre of the proximal articular surface; point b: centre of the distal articular surface; j: proximal joint orientation line; k: distal joint orientation line; ma: mechanical axis. (B) Tibial plateau angle (TPA): Point a: proximal most point of intercondylar eminence of tibia; Point b: centre of talus; ma: mechanical axis connecting point a and b; j: joint orientation line; p: line drawn peripendicular to ma; (C) Proximal tibial axis angle (PTA): Point c: midpoint of the craniocaudal cortices of the tibia at 1/2 the length of the tibia; point d: midpoint of the craniocaudal cortices of the tibia at the distal 1/3 of the length of the tibia; point t: distal aspect of the tibial crest; point e: craniocaudal midpoint between the distal aspect of the tibial crest and diaphyseal tibial axis; point a: cranial aspect of the medial tibial condyle; p: straight line connecting the cranial aspect of the medial tibial condyle and the craniocaudal midpoint between the distal aspect of the tibial crest and the diaphyseal tibial axis; D) Mechanical cranial proximal tibial angle (mCrPTA), mechanical caudal proximal tibial angle (mCdPTA), mechanical cranial distal tibial angle (mCrDTA) and mechanical caudal distal tibial angle (mCdDTA). j: proximal joint orientation line; k: distal joint orientation line; ma: mechanical axis. (E) Patellar ligament to patella length ratio (PL:P): line a: drawn on widest length of patella; line b: distal most point of patella to proximal tibial tuberosity.(D) Mechanical cranial proximal tibial angle (mCrPTA), mechanical caudal proximal tibial angle (mCdPTA), mechanical cranial distal tibial angle (mCrDTA) and mechanical caudal distal tibial angle (mCdDTA). j: proximal joint orientation line; k: distal joint orientation line; ma: mechanical axis. (E) Patellar ligament to patella length ratio (PL:P): line a: drawn on widest length of patella; line b: distal most point of patella to proximal tibial tuberosity.

serum levels of calcium, phosphorus, and alkaline phosphatase.

Statistical analysis

The data analysis was performed using SPSS version 24.0 software. Obtained values of all angular parameters were categorised into four groups based on DI. The mean and standard deviation for each angle in different groups were calculated. Calculated means of groups were compared among groups using one-way ANOVA, followed by the Duncan Multiple Range test. Karl Pearson's correlation coefficient was utilized to assess the correlation between DI and angular parameters of the femur and tibia. Significance was determined at $P < 0.05$ or $P < 0.01$.

Results and Discussion

Incidence of hip dysplasia

A total of 369 dogs exhibiting hind limb lameness were presented to the outpatient unit of the Department of Veterinary Surgery and Radiology during the one-year period from July 1 2022 to June 31 2023. Among them, 65 dogs (17.61%) were diagnosed to be suffering from CHD. Richardson (1992) noted that CHD represented a prevalent issue in veterinary practice, comprising as much as 30% of orthopaedic cases. Among 65 dysplastic dogs 40 were selected for the study excluding the dogs with other systemic affections, which were considered not fit for anaesthesia. Out of 40 dysplastic dogs, 21 (53%) were males, consistent with Simon (2010) and Maciel *et al.* (2019). This contradicts findings by Loder and Todhunter (2017) and Seema (2022) where female dogs had a higher incidence. Among the 11 distinct breeds represented, Labrador Retrievers had the highest incidence (47.5%), followed by German shepherds, Rottweilers and others, aligning with Ohlerth *et al*. (2001) and Simon (2010). Large and medium-sized breeds, as noted by King (2017), had a higher CHD incidence.

In the current study, it was observed that hip dysplasia had a higher incidence in young dogs. The incidence of hip dysplasia in young dogs under one year might stem from factors such as rapid early growth, disproportionate skeletal and muscular development, excessive loading of articular areas, and tearing or stretching of the round ligament (Kasstrom, 1975). Likewise, Citi *et al*. (2005) documented the highest incidence among those less than 12 months old. The reduced observation of clinical signs in middle-aged dogs could be attributed to the fact that heavy musculature around the rump region results in reduced laxity of the hip joint and thus reduction in symptoms (Weigel and Wasserman, 1992).

Orthopaedic examination

The mean lameness score was 2.750±0.147, ranging from 1 to 4. In present study, the majority of animals diagnosed with hip dysplasia showed lameness scores in the range of 2-4. The observations are consistent with the findings of Singh (2019) and Seesma (2022) who reported mean lameness scores of 2.67±0.21 and 2.67±0.52, respectively, in dogs with hip dysplasia. The higher lameness score observed in hip dysplastic dogs may be attributed to secondary osteoarthritic changes in the hip joint (Barr *et al*., 1987). Additionally, some dogs with lower DI showed a higher degree of lameness, possibly due to concurrent stifle affections (Powers *et al*., 2005).

The study identified varying degrees of muscle wasting, categorised as mild (42.50%), moderate (40%), and severe (17.50%). These findings highlight the variation in muscle atrophy among patients, which correlates with the duration of lameness or chronicity of pain. Lameness durations reported by pet owners ranged from 3 days to 6 months. These results align with the observations made by Duff and Campbell (1977) linking chronic hip joint pain to thigh muscle wasting due to disuse. However, Maruthi (2016) who noted no correlation between thigh muscle mass diameter and hip dysplasia.

The dogs exhibited a diverse array of clinical signs, such as decreased activity levels, reluctance to climb stairs, wide and narrow base stance, and difficulty in rising from a resting position. Many of them displayed a distinct posture characterised by a hyperextended hock joint and demonstrated abnormal gaits including bunny hopping, waddling and skipping. These observations align closely with previous studies by Fry and Clark (1992), Seesma (2022) and Alsada (2023). Similarly, Demko and McLaughlin (2005) documented symptoms in mature dogs resembling osteoarthritis, such as exacerbated lameness following periods of rest or exercise, reluctance to jump, and pelvic limb atrophy. These emphasise the consistent occurrence of hip dysplasia and its diverse clinical manifestations.

Physical examination

All the animals demonstrated pain upon palpation and manipulation of the hip and stifle joints, consistent with the findings of Fry and Clark (1992). In the present study, the mean±SE pain score of the hip joints was 1.72±0.01. The mean±SE pain score of stifle joints was 15±0.00. Singh (2019) reported a pain score of 2.50±0.22 for hip joints with CHD. The reduced pain scores observed in this study might be attributed to previous treatment adopted using nonsteroidal anti-inflammatory drugs (Anderson, 2011). It also may be attributed to interpersonal variation in observation.

Vidoni *et al*. (2021) concluded that the Ortolani test offers greater accuracy compared to the tests devised by Barlow and Barden. Ginja *et al*. (2008) highlighted the Ortolani test as the standard physical manipulation test for detecting hip joint laxity in dogs. A positive Ortolani sign indicates increased hip joint laxity, attributed to delayed muscular development and increased synovial effusion (Chalman and Butler,

Table 2: Results correlation of different parameters with Distraction Index.

Proximal femoral angles					Proximal femoral angles
Variables	**Correlation**	**P-value**	**Variables**	**Correlation**	**P-value**
NA	-0.763**	0	aLDFA	0.191	0.237
AOI	0.008	0.959	mLDFA	0.148	0.363
aLPFA	-0.316*	0.047	QA	0.384*	0.014
mLPFA	0.265	0.099	FVA	0.159	0.327
Proximal femoral angles			**Proximal femoral angles**		
mCrPTA	0.252	0.116	mCrDTA	0.020	0.903
mCdPTA	0.004	0.980	mCdDTA	0.304	0.057
TPA	0.336*	0.034	mMDTA	0.167	0.303
mMPTA	0.477**	0.002			
PTA	0.355*	0.025			
Patellar parameters			*** Significant at 0.01 level;*		
TWA	-0.271	0.091	** Significant at 0.05 level;*		
TWD	0.057	0.726			
PL:P	0.197	0.236			

Table 3: Results of comparison of proximal femoral angles between groups.

Variables	Group I	Group II	Group III	Group IV	F-value(P-value)
NA	99.03^{a}±2.25	94.86^{a}±2.39	83.39^{b}±6.72	61.00^{c}±4.15	29.383** (<0.001)
AOI	136.34±1.71	136.98±2.32	131.39±1.24	135.7±1.76	0.812^{ns} (0.491)
mLPFA	99.6^{b}±1.63	103.06^{ab}±2.13	107.48^{a}±3.04	104.77^{ab}±1.36	2.837* (0.044)
aLPFA	103.9±2.25	107.63±2.2	113.21±2.47	107.6±1.27	2.210^{ns} (0.094)

**Significant at 0.01 level; * Significant at 0.05 level; ns non-significant
Means having different letter as superscript differ significantly within a raw

1985). Conversely, a negative Ortolani sign may suggest good joint congruity (Syrcle *et al*., 2017).

In the present study, 18 dogs exhibited bilateral positivity and 6 dogs showed unilateral positivity for the Ortolani manoeuvre. All joints testing positive for the Ortolani manoeuvre had a DI exceeding 0.21, consistent with findings by Puerto *et al*. (1999), who also correlated the Ortolani manoeuvre with DI, particularly in the absence of secondary osteoarthritic changes. Notably, one dog yielded a false positive result with a lower DI. This could be attributed to the puppy laxity as reported by Vidoni *et al*. (2021), who observed that in dogs around four months of age, where skeletal and muscular development is still progressing, passive laxity may be present before reaching full maturity.

In contrast, four dogs tested negative for the Ortolani manoeuvre despite having DI more than 0.4. The false negative result could likely be due to osteoarthritic changes. Schachner and Lopez (2015) documented similar instances in mature dogs with significant joint laxity, where a negative Ortolani test occurred due to fibrosis of the joint capsule. Therefore, a negative Ortolani result may not necessarily indicate a normal hip joint radiographically. Consequently, Puerto *et al*. (1999) emphasised the importance of combining physical examination and radiographic evaluation to comprehensively assess hip joint laxity, a practice upheld in our study.

Barden's sign

Bardens and Hardwick (1968) endorsed Bardens test for early diagnosis of hip dysplasia, relying on greater trochanter mobility. In the present study out of 40 dogs, five were bilaterally positive and five unilaterally. Those exhibiting a positive Bardens sign had a DI more than 0.3. This indicates reliability of Bardens sign in identifying joints with higher hip laxities. The high number of negative results may stem from the lack of objective trochanter rise measurement methods during Barden's manoeuvre. This manoeuvre could predict hip dysplasia, as observed in the present study and as reported by Adams *et al*. (2000) in Golden Retrievers.

Position of patella and grading of patella luxation

Out of 40 dogs with CHD, 32 (80%) were diagnosed positive for patella luxation either unilaterally or bilaterally with various grades. Smith *et al*. (1999) stated that clinically normal patients may have a certain degree of laxity in the stifle joint, which could be misdiagnosed as grade I patellar luxation (PL). This error has to be considered in the present study also. Twelve out of 40 dogs (30%) were diagnosed with grade II or grade IV PL either unilateral or bilateral. The association between CHD and PL was more evident in this study when compared with that of smith *et al.* (1999), where the authors found that only 24% of dogs had concurrent CHD and PL. In the present study, the limbs affected with patella luxation

were grouped based on the DI of the ipsilateral hip joint. The highest incidence of PL was noticed in group I where DI was less than 0.3. This was in accordance with the findings of smith *et al*. (1999), where the authors identified certain degree of laxity in a normal stifle joint that could be misdiagnosed as grade I PL. The incidence of PL followed a descending pattern among group IV (DI above 0.7), group III (DI 0.5 to 0.7) and group II (0.3 to 0.5). Even though higher incidence of the condition was noticed in severe case of CHD, it could not be concluded that CHD and PL are closely associated. It should be noted that both the conditions may develop concurrently or individually.

Cranial drawer sign and tibial compression test

Might *et al.* (2013) emphasised the high sensitivity of the drawer test in diagnosing CrCLR. In the present study among the 40 dogs examined, five showed bilateral positive results while six displayed unilateral positivity. 25% of stifle joints in group I showed a positive cranial drawer sign followed by 6% in group II, 19% in group III, and 50% in group IV. Even though group IV limbs had highest incidence and group II had lowest incidence, an exact correlation between CHD and CrCLR could not be identified in present study.

Five dogs, which tested positive for high grade of PL tested positive for cranial drawer sign also. This finding is in agreement with the observations of Campbell *et al*. (2010) who observed that the dogs with higher grades of patella luxation tend to have CrCL insufficiency. All the dogs tested negative for the tibial compression test. As physical examination findings provide suggestive evidences, treatment planning should not solely rely on such findings.

Radiographic examination

The recorded mean and standard deviation values of proximal femoral angles of groups I, II, III and IV are represented in table 3. The correlation coefficients values of these angles with DI are represented in table 2. A notable decrease in the NA occurred as the DI increased. Significant differences in NA were observed between groups ($P \leq 0.01$). The decrease in the NA between groups may be due to increased hip joint incongruence (Norberg, 1961; Olsson *et al*., 1961). Furthermore, a significant and moderate negative correlation was found between the NA and DI, with a correlation coefficient of -0.763 ($P \leq 0.01$).

The mean and standard deviation values indicate non-significant differences in AOI among the groups. Martins *et al*. (2012) and Seesma (2022) also observed that no significant difference in AOI exists between normal and dysplastic dogs. Furthermore, there exists a slight positive correlation between AOI and DI, reinforcing the conclusion of Martins *et al*. (2012). The findings of the present study are contradictory to the observations made by Arnoczky and Torzilli (1981), and Madsen and Svalastoga (1994).

The aLPFA values among the groups revealed statistically nonsignificant variation. The 2aLPFA values showed a negative correlation with the distraction index, with a significant correlation coefficient of -0.316 at 0.05 level. The decrease in aLPFA values may be due to elevated abductor forces in the dysplastic hip (Weigel and Wasserman, 1992), which alters the alignment of the proximal joint orientation line.

Statistically significant variations were noted in mLPFA values among the groups ($P \leq 0.05$). A weak positive correlation exists between mLPFA and DI, which suggests alterations in the load bearing axis of the limbs.

Distal femoral angles

The values of distal femoral angles of groups I, II, III, and IV are represented in table 4. The correlation coefficients values of these angles with DI are represented in table 2. When mean and standard deviation comparing aLDFA across the groups, statistically significant differences were noticed. The aLDFA values in a dog with grade IV PL were higher, which was consistent with the findings of Soparat *et al*. (2012) and Barnes *et al*. (2015), who noted that aLDFA exaggerates in higher grades of patella luxation, leading to excessive femoral varus. Despite the weak positive correlation between aLDFA and the DI, it is recommended to assess aLDFA in dogs with CHD. This evaluation helps to identify femoral varus deformity, which can predispose to PL and CrCLR (Dudley *et al*., 2006; Mostafa *et al*., 2008).

No statistically significant difference was observed in mLDFA among the groups. The mLDFA displays a weak positive correlation of 0.148 with the DI.

There existed a noticeable increase in the QA value from group I (20.06±0.9) to group IV (23.26±1.00). There appears to be a potential trend, approaching significance, in QA. Additionally, QA exhibited a significant positive correlation with the DI. Three of the five small breed dogs were diagnosed with grade I and IV PL. These findings were consistent with findings reported by Mortari *et al*. (2009) and Pinna and Romagnoli (2017).

Significant variations existed in FVA values among the groups. FVA values showed a weak positive correlation with DI, which suggested that as DI increases FVA values also rise. Hulse (1993) noted that higher FVA values potentially predispose to MPL. Thus from the present study it could be derived that higher grades of CHD predispose the animal to MPL. Dudley *et al*. (2006) and Soparat *et al*. (2012) observed that varus deformity of the distal femur (increased FVA values) shifts the long axis of quadriceps femoris muscles medially leading to patellar luxation or CrCL insufficiency. Thus it could be concluded that CHD predisposes the animal to stifle affections like PL and CrCL insufficiency.

Proximal tibial angles

The values of proximal tibial angles of groups I, II, III and IV are represented in table 5. The correlation coefficient values of this angle with DI are represented in table 2. According to Dismukes *et al*. (2007), mMPTA was evaluated to determine the extent of valgus or varus alignment present in the proximal tibia. Olimpo *et al*. (2016) found significantly higher mMPTA values in dogs with PL. In this study, mMPTA values increased gradually with higher DI, although the variance among groups did not reach statistical significance. However, a moderate positive correlation between mMPTA and DI significant at 0.01 level was observed in this study. This suggests that as the severity of CHD increases, it may lead to proximal tibial valgus, identified as a crucial risk factor for PL.

No significant difference was found in mCrPTA and mCdPTA among the groups. Both mCrPTA and mCdPTA showed a positive correlation with DI.

Slocum and Devine (1983) theorised that TPA significantly influences forces on the canine cranial cruciate ligament. In the present study, TPA increased gradually with increasing DI, but the differences among the groups were not statistically significant. Changes in TPA positively correlated with DI (P<0.05). However, the group average values observed were below those reported by Su *et al*. (2015), who documented a TPA value of 29.2 ±0.8 degrees in healthy medium to large-breed dogs. This minimal alteration in TPA in this study may be attributed to younger age of majority of the dogs, where the alterations in the tibial plateau were not predominantly evident. Janovec *et al*. (2017) found higher TPA values in dogs with CrCLR. The present study noted a positive association between TPA and DI, indicating that severe CHD could lead to a steeper tibial plateau, a major risk factor for CrCLR.

Osmond *et al*. (2006) emphasised PTA as the relationship between the proximal tibial shaft and the mid-shaft of the tibia. The present study found no statistically significant difference in PTA among groups, but it did observe a statistically significant positive correlation with DI (P<0.05). This elucidates that as the severity of CHD increases, it may alter the alignment of the proximal tibia, which may predispose to concurrent affections in the stifle joint. Mean PTA values recorded in the present study were lower than those reported by Witte (2015), for healthy

Table 4: Results of comparison of distal femoral angles between groups.

Variables	Group I	Group II	Group III	Group IV	F-value(P-value)
aLDFA	95.06±1.21	95.18±1.46	98.51±1.35	97.74±1.33	1.332^{ns} (0.270)
mLDFA	99.21±0.92	99.78±1.17	102.99±1.85	101.276±0.93	1.698^{ns} (0.175)
QA	20.06±0.9	20.21±1.29	24.15±2.46	23.26±1	2.688^{ns} (0.052)
FVA	9.08^{b}±0.86	8.77^{b}±1.43	12.60^{ab}±1.74	12.67^{a}±1.19	3.018* (0.035)

* Significant at 0.05 level; ns non-significant
Means having different letter as superscript differ significantly within a raw

Table 5: Results of comparison of proximal tibial angles between groups.

Variables	Group I	Group II	Group III	Group IV	F-value(P-value)
mCrPTA	115.06±0.76	114.66±1.15	115.28±1.64	116.55±1.08	0.680^{ns} (0.567)
mCdPTA	64.99±0.76	65.41±1.16	64.9±1.6	63.56±1.06	0.650^{ns} (0.585)
TPA	19.38±0.55	20.12±1.21	21.69±2.11	22.04±1.13	1.632^{ns} (0.189)
DPA	10.18±0.97	8.92±0.74	8.84±0.87	10.49±1.25	0.477^{ns} (0.699)
mMPTA	93.29±0.71	93.69±0.95	93.9±0.91	95.39±1.32	0.914^{ns} (0.438)

ns non-significant

Table 6: Results of comparison of distal tibial angles between groups

Variables	Group I	Group II	Group III	Group IV	F-value(P-value)
mCrDTA	89.73±0.68	88.55±0.86	89.28±0.78	87.74±0.69	1.573^{ns} (0.203)
mCdDTA	90.32±0.67	91.5±0.87	90.81±0.74	92.32±0.71	1.548^{ns} (0.209)
mMDTA	93.11±1.13	93.81±1.09	94.68±1.43	94.35±0.85	0.361^{ns} (0.781)

ns non-significant

Table 7: Results of comparison of patellar parameters between groups.

Variables	Group I	Group II	Group III	Group IV	F-value(P-value)
TWA	140.83^{a}±2.06	138.14^{ab}±2.23	138.39^{ab}±4.24	132.95^{b}±1.67	2.849* (0.043)
TWD	2.57±0.18	2.63±0.28	2.31±0.3	2.88±0.16	0.878^{ns} (0.457)
PL:P	1.55±0.05	1.42±0.07	1.58±0.12	1.52±0.09	0.579^{ns} (0.630)

**Significant at 0.05 level; ns non-significant*
Means having different letter as superscript differ significantly within a raw

medium to large size dog breeds. The fact that the breeds of dogs ranged from toy breeds to giant breeds, might be attributed to the lower PTA values observed in this study.

Distal tibial angles

The values of distal tibial angles of group I, II, III and IV are represented in table 6. The correlation coefficient values of this angle with DI are represented in table 2. There was no significant difference found in the comparison of mMDTA values among the groups. Additionally, a positive correlation was observed between mMDTA and DI, but it did not reach a statistically significant level.

There were no notable distinctions noted when the groups were compared in terms of both mCrDTA and mCdDTA. However, it showed a weak positive correlation with DI. Nevertheless, these correlations did not reach a statistically significance level. Probably this could be the first study which checked the correlation between CHD and distal tibial angles.

Patellar parameters

The values of patellar parameters of group I, II, III and IV are represented in table7. The correlation coefficient values of this angle with DI are represented in table 2. There are significant variations among at least two groups concerning the TWA variable with a weak negative correlation between TWA and DI. As DI rises, TWA generally decreases, and vice versa. However, the strength of this correlation is relatively weak, as indicated by the absolute value of the correlation coefficient. There is no statistically significant difference between the groups for TWD and no significant correlation with the DI. Previous studies found significant differences in dogs with and without PL. Dogs with trochlear dysplasia are at higher risk of patellar luxation due to groove abnormalities. Brattstrom (1964) and Dejour *et al.* (1994) linked trochlear dysplasia to recurrent patellar subluxation in 85% of symptomatic cases. Huri *et al.* (2012) suggested that facet slope angles affect subluxation forces, while Garnoeva (2021) highlighted high sulcus angles and shallow trochlear depth as contributing factors for PL.

The PL:P ratio did not show statistically significant differences among the groups and no significant correlation with DI. Johnson *et al.* (2006) observed a higher proximal vertical patellar position in large-breed dogs with MPL compared to those with normal stifles, which was noticed in this study in the case of higher grades of PL. It was observed that dogs affected with MPL had patella alta and those with LPL had Patella baja, which was consistent with the findings of Mostafa *et al.* (2008).

In conclusion, the findings of this study revealed a noteworthy positive correlation between the distraction index and various anatomical parameters including FVA, QA of distal femoral angles, mMPTA, TPA, and PTA of proximal tibial angles. According to existing literature, higher values of 351 these parameters may heighten the susceptibility to patellar luxation (PL) and cranial cruciate ligament rupture (CrCLR) in the stifle joint.

References

Adams, W.M., Dueland, R.T., Daniels, R., Fialkowski, J.P. and Nordheim, E.V. 2000. Comparison of two palpation, four radiographic and three ultrasound methods for early detection of mild to moderate canine hip dysplasia. Vet. Radiol. Ultrasound. **41**: 484-490.

Alsada, I.H.A. 2023. Hip dysplasia in large breed of dogs. One. Hlth. Triad. **3**: 202-207.

Anderson, A. 2011. Treatment of hip dysplasia. J. Small Anim. Pract. **52**: 182-189.

Arnoczky, S.P. and Torzilli, P.A. 1981. Biomechanical analysis of forces acting on the canine hip. Am. J. Vet. Res. **42**: 1581-1585.

Bardens, J.W. and Hardwick, H. 1968. New observations on the diagnosis and cause of hip dysplasia. Vet. Med. Small Anim. Clin. **63**: 238-245.

Barnes, D.M., Anderson, A.A., Frost, C. and Barnes, J. 2015. Repeatability and reproducibility of measurements of femoral and tibial alignment using computed tomography multiplanar reconstructions. Vet. Surg. **44**: 85-93.

Barr, A.R.S., Denny, H.R. and Gibbs, C. 1987. Clinical hip dysplasia in growing dogs: the long-term results of conservative management. J. Am. Anim. Pract. **28**: 243-252.

Boonchaikitanan, P., Choisunirachon, N. and Soontornvipart, K. 2019. A feasibility of ultrasonographic assessment for femoral trochlear depth and articular cartilage thickness in canine cadavers. Thai. J. Vet. Med. **49**: 257-264.

Bound, N., Zakai, D., Butterworth, S.J. and Pead, M. 2009. The prevalence of canine patellar luxation in three centres. Vet. Comp. Orthop. Traumatol. **22**: 32-37.

Bound, N., Zakai, D., Butterworth, S.J. and Pead, M. 2009. The prevalence of canine patellar luxation in three centres. Vet. Comp. Orthop. Traumatol. **22**: 32-37.

Brattstrom, H. 1964. Shape of the intercondylar groove normally and in recurrent dislocation of patella: a clinical and x-ray anatomical investigation. Acta Orthop. Scand. **35**: 1-148.

Campbell, C.A., Horstman, C.L., Mason, D.R. and Evans, R.B. 2010. Severity of patellar luxation and frequency of concomitant cranial cruciate ligament rupture in dogs: 162 cases (2004–2007). J. Am. Vet. Med Assoc. **8**: 887-891.

Chalman, J.A. and Butler, H.C. 1985. Coxofemoral joint laxity and the Ortolani sign. J. Am. Anim. Hosp. Assoc. **21**: 671-676.

Citi, S., Vignoli, M., Roni, F. and Morgan, J.P. 2005. A radiological study of the incidence of unilateral canine hip dysplasia. Schweiz. Arch. Tierheilkd. **147**: 173-178.

Comhaire, F.H. and Schoonjans, F.A. 2011. Canine hip dysplasia: the significance of the Norberg angle for healthy breeding. J. Small Anim. Pract. **10**: 536-542.

Dejour, H., Walch, G., Nove-Josserand, L. and Guier, C.H. 1994. Factors of patellar instability: an anatomic radiographic study. Knee Surg. Sports Traumatol. Arthrosc. **2**: 19-26.

Demko, J. and McLaughlin, R. 2005. Developmental orthopedic disease. *Vet. Clin. North Am. Small. Anim. Pract.* **35**: 1111-1135.

Dismukes, D.I., Tomlinson, J.L., Fox, D.B., Cook, J.L. and Song, K.J.E. 2007. Radiographic measurement of the proximal and distal mechanical joint angles in the canine tibia. Vet. Surg. **36**: 699-704.

Dudley, R.M., Kowaleski, M.P., Drost, W.T. and Dyce, J. 2006. Radiographic and computed tomographic determination of femoral varus and torsion in the dog. Vet. Radiol. Ultrasound **47**: 546-552.

Duff, R. and Campbell, J.R., 1977. Long-term results of excision arthroplasty of the canine hip. Vet. Rec. **10**: 181-184.

Fry, T.R. and Clark, D.M. 1992. Canine hip dysplasia: clinical signs and physical diagnosis. Vet. Clin. North Am. Small Anim. Pract. **22**: 551-558.

Garnoeva, R.S. 2021. Evaluation of trochlear dysplasia in dogs with medial patellar luxation-comparative studies. Acta Sci. Vet. 49.1845

Ginja, M.M.D., Gonzalo Orden, J.M., Melo Pinto, P., Bulas Cruz, J., Orden, M.A., San Roman, F., Llorens Pena, M.P. and Ferreira, A.J.A. 2008. Early hip laxity examination in predicting moderate and severe hip dysplasia in Estrela mountain dog. J. Small Anim. Pract. **49**: 641-646.

Ginja, M.M.D., Silvestre, A.M., Gonzalo-Orden, J.M. and Ferreira, A.J.A. 2010. Diagnosis, genetic control and preventive management of canine hip dysplasia: a review. Vet. J. **184**: 269-276.

Glassman, M., Hofmeister, E., Weh, J.M., Roach, W., Torres, B., Johnston, S. and Budsberg, S. 2011. Radiographic quantitative assessment of caudal proximal tibial angulation in 100 dogs with cranial cruciate ligament rupture. Vet. Surg. **40**: 830-838.

Guenego, L., Payot, M., Charru, P. and Verwaerde, P. 2017. Comparison of tibial anatomical-mechanical axis angle between predisposed dogs and dogs at low risk for cranial cruciate ligament rupture. Vet. J. **225**: 35-41.

Hulse, D.A. 1993. Medial patellar luxation in the dog. *In*: Disease Mechanisms in Small Animal Surgery, M.J. Bojrab (Ed), 2nd edn. Lea & Febiger, Philadelphia, USA. pp 808–817.

Huri, G., Atay, O.A., Ergen, B., Atesok, K., Johnson, D.L. and Doral, M.N. 2012. Development of femoral trochlear groove in growing rabbit after patellar instability. Knee Surg. Sports Traumatol. Arthrosc. **20**: 232-238.

Janovec, J., Kyllar, M., Midgley, D. and Owen, M. 2017. Conformation of the proximal tibia and cranial cruciate ligament disease in small breed dogs. Vet. Comp. Orthop. Traumatol. **30**: 178-183.

Johnson, A.L., Broaddus, K.D., Hauptman, J.G., Marsh, S., Monsere, J. and Sepulveda, G. 2006. Vertical patellar position in large breed dogs with clinically normal stifles and large breed dogs with medial patellar luxation. Vet. Surg. **35**: 78-81.

Kasstrom, H. 1975. Nutrition, weight gain and development of hip dysplasia. An experimental investigation in growing dogs with special reference to the effect of feeding intensity. Acta. Radiol. Suppl. **344**: 135-179.

King, M.D., 2017. Etiopathogenesis of canine hip dysplasia, prevalence, and genetics. Vet. Clin. North. Am. Small Anim. Pract. **4**: 753-767.

Loder, R.T. and Todhunter, R.J. 2017. The demographics of canine hip dysplasia in the United States and Canada. J. Vet. Med. 2017: 1-15.

Lust, G. 1997. An overview of the pathogenesis of canine hip dysplasia. J. Am. Vet. Med. Assoc. **210**: 1443-1445.

Maciel, M., de Oliveira Reusing, M.S., Junior, J.A.V., Tasqueti, U.I. and Weber, S.H. 2019. Occurrence of canine hip dysplasia, cranial cruciate ligament rupture and patellar luxation in dogs in a retrospective study of 100 orthopedic cases. Rev. Acad. Cienc. Anim. 17.

Madsen, J.S. and Svalastoga, E. 1994. Inclination and anteversion of collum femoris in hip dysplasia and coxarthritis. Acta. Vet. Scand. **35**: 115.

Marsolais, G.S., Dvorak, G. and Conzemius, M.G., 2002. Effects of postoperative rehabilitation on limb function after cranial cruciate ligament repair in dogs. J. Am. Vet. Med Assoc. **9**: 1325-1330.

Martins, J., Ferreira, A.J. and Ginja, M.M. 2012. Morphometric assessment of the hip joint in the Estrela Mountain Dog breed. Vet. Comp. Orthop. Traumatol. **25**: 202-210.

Maruthi. S.T. 2016. Clinical evaluation of surgical denervation of coxofemoarl joint and medical theraphy for the management of hip dysplsia in dogs. MVSc thesis, Kerala Veterinary and Animal Sciences University, Pookode (Kerala), India P 97.

Might, K.R., Bachelez, A., Martinez, S.A. and Gay, J.M. 2013. Evaluation of the drawer test and the tibial compression test for differentiating between cranial and caudal stifle subluxation associated with cruciate ligament instability. Vet. Surg. **42**: 392-397.

Mortari, A.C., Rahal, S.C., Vulcano, L.C., da Silva, V.C. and Volpi, R.S. 2009. Use of radiographic measurements in the evaluation of dogs with medial patellar luxation. Can. Vet. J. **50**: 1064.

Mostafa, A.A., Griffon, D.J., Thomas, M.W. and Constable, P.D. 2008. Proximodistal alignment of the canine patella: radiographic evaluation and association with medial and lateral patellar luxation. Vet. Surg. **37**: 201-211.

Norberg, I. 1961. Hoftledsdysplasi hos hund. Hundsport. **69**: 13-15.

Ohlerth, S., Lang, J., Busato, A. and Gaillard, C. 2001. Estimation of genetic population variables for six

radiographic criteria of hip dysplasia in a colony of Labrador Retrievers. Am. J. Vet. Res. **62**: 846-852.

Olimpo, M., Piras, L.A. and Peirone, B. 2016. Pelvic limb alignment in small breed dogs: a comparison between affected and free subjects from medial patellar luxation. Vet. Ital. **52**: 45-50.

Olsson, S.E., 1961. Roentgen examination of the hip joints of German shepherd dogs. Adv. Small Anim. Pract. **3**: 117-118.

Osmond, C.S., Marcellin little, D.J., Harrysson, O.L. and Kidd, L.B. 2006. Morphometric assessment of the proximal portion of the tibia in dogs with and without cranial cruciate ligament rupture. Vet. Radiol. Ultrasound. **47**: 136-141.

Paley, D. 2002. Normal lower limb alignment and joint orientation. *In*: Principles of Deformity Correction, Herzenberg, J.E. (Ed.). Berlin, Springer-Verlag, Philadelphia, USA. pp 1-18.

Pinna, S. and Romagnoli, N. 2017. Radiographic measurement of the quadriceps angle in dogs. Plos one **12**: e0185833.

Powers, M.Y., Martinez, S.A., Lincoln, J.D., Temple, C.J. and Arnaiz, A. 2005. Prevalence of cranial cruciate ligament rupture in a population of dogs with lameness previously attributed to hip dysplasia: 369 cases (1994–2003). J. Am. Vet. Med. Assoc. **227**: 1109-1111.

Puerto, D.A., Smith, G.K., Gregor, T.P., LaFond, E., Conzemius, M.G., Cabell, L.W. and McKelvie, P.J. 1999. Relationships between results of the Ortolani method of hip joint palpation and distraction index, Norberg angle, and hip score in dogs. *J. Am. Vet. Med. Assoc.* **214**: 497-501.

Reif, U. and Probst, C.W. 2003. Comparison of tibial plateau angles in normal and cranial cruciate deficient stifles of Labrador retrievers. Vet. Surg. **32**: 385-389.

Reif, U., Dejardin, L.M., Probst, C.W., DeCamp, C.E., Flo, G.L. and Johnson, A.L. 2004. Influence of limb positioning and measurement method on the magnitude of the tibial plateau angle. Vet. Surg. **33**: 368-375.

Richardson, D. C. 1992. The role of nutrition in canine hip dysplasia. Vet. Clin. North Am. Small Anim. Pract. **22**: 529-540.

Rumph, P.F. and Hathcock, J.T. 1990. A symmetric axis based method for measuring the projected femoral angle of inclination in dogs. Vet. Surg**. 19**: 328-333.

Runge, J.J., Kelly, S.P., Gregor, T.P., Kotwal, S. and Smith, G.K. 2010. Distraction index as a risk factor for osteoarthritis associated with hip dysplasia in four large dog breeds. J. Small Anim. Pract. **5**: 264-269.

Schachner, E.R. and Lopez, M.J. 2015. Diagnosis, prevention, and management of canine hip dysplasia: A review. Vet. Med. Res. Reports. **6:** 181-192.

Seesma. S. 2022. Early diagnosis of hip dysplasia and its surgical management by juvenile pubic symphysiodesis in puppies. MVSc thesis, Kerala Veterinary and Animal Sciences University, Pookode (Kerala), India. P 100.

Simon, S.M., Ganesh, R., Ayyappan, S., Rao, G.D., Suresh Kumar, R., Manonmani, M. and Das, B.C. 2010. Incidence of canine hip dysplasia: A survey of 272 cases. Vet. World **3**: 219-220.

Singh, S. 2019. Clinical studies on nutraceuticals versus autologous uncultured bone marrow mononucleated stem cells (BMNSC) for treatment of hip dysplasia in canine. MVSc thesis, Bihar Animal Sciences University, Patna (Bihar), India. P 120.

Slocum, B. and Devine, T., 1983. Cranial tibial thrust: a primary force in the canine stifle. J. Am. Vet. Med Assoc. **4**: 456-459.

Smith, G.K., Langenbach, A., Green, P.A., Rhodes, W.H., Gregor, T.P. and Giger, U., 1999. Evaluation of the association between medial patellar luxation and hip dysplasia in cats. J. Am. Vet. Med Assoc. **1**: 40-45.

Soparat, C., Wangdee, C., Chuthatep, S. and Kalpravidh, M. 2012. Radiographic measurement for femoral varus in Pomeranian dogs with and without medial patellar luxation. Vet. Comp. Orthop. Traumatol. **25**: 197-201.

Su, L., Townsend, K.L. Au, J. and Wittum, T.E. 2015. Comparison of tibial plateau angles in small and large breed dogs. Can. Vet. J. **56**: 610.

Syrcle, J. 2017. Hip dysplasia: clinical signs and physical examination findings. Vet. Clin. North Am. Small Anim. Pract. **47**: 769-775.

Tomlinson, J., Fox, D., Cook, J.L. and Keller, G.G. 2007. Measurement of femoral angles in four dog breeds. Vet. Surg. **36**: 593-598.

Ulfelder, E.H., Hudson, C.C. and Beale, B.S. 2019. Correlation of distraction index with arthroscopic findings in juvenile dogs with hip dysplasia. Vet. Surg. **48**: 1050-1057.

Verhoeven, G., Fortrie, R., Van Ryssen, B. and Coopman, F. 2012. Worldwide screening for canine hip dysplasia: where are we now. Vet. Surg. **1**: 10-19.

Vidoni, B., Bauer, V., Bockstahler, B., Gumpenberger, M., Tichy, A. and Aghapour, M. 2021. Early diagnosis of canine hip laxity: correlation between clinical orthopedic examinations and the FCI scoring method in a closed cohort of rottweilers. Animals **11**: 416.

Weigel, J.P. and Wasserman, J.F. 1992. Biomechanics of the normal and abnormal hip joint. Vet. Clin. North Am. Small Anim. Pract. **22**: 513–528.

Witte, P.G. 2015. Tibial anatomy in normal small breed dogs including anisometry of various extracapsular stabilizing suture attachment sites. Vet. Comp. Orthop. Traumatol. **28**: 331-338.