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REVIEW ARTICLE

MORPHOMETRIC EVALUATION OF THE HIP JOINT IN DOGS

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Ethical considerations: When reporting experiments on animals Observation of the ARRIVE guidelines 2.0: Updated guidelines for reporting animal research, published in July 14, 2020 (https://doi.org/10.1371/journal.pbio.3000410), is applied. The authors ensure that all procedures were performed in compliance with the guidelines for animal care of their institutions or with national/international guidelines.

ABSTRACT

Hip dysplasia represents the most prevalent non-traumatic disease leading to lameness in dogs, which subsequently causes secondary joint pathologies such as arthrosis and arthritis. Diagnosis and selection for breeding use radiographic evaluation of the ventrodorsal projection of the hip joint. Early detection and treatment can halt or reverse the disease progression. In veterinary medicine, various radiological measurements are applied to evaluate such anatomical abnormalities. These measurements include the Norberg angle, percentage coverage of the femoral head, and various indices related to the acetabulum and proximal femur. The differences in measurements between breeds are significant and reflect differences in body conformation. Ventrodorsal radiographs are crucial for the diagnosis, screening and monitoring of hip dysplasia. Lack of reference values for morphometric measurements in dogs highlights the need for further research.

Key words: acetabulum; geometry; hip; proximal femur; radiography

INTRODUCTION

The most prevalent non-traumatic disease that causes lameness in dogs is dysplasia of the hip joint. This disease leads to secondary joint disease, arthrosis, and arthritis, and clinical signs such as pain and lameness correspond to this [12]. Many screening procedures use radiographic evaluation of the ventrodorsal projection of the hip joint for selection into breeding. To confirm the joint disease, the Federation Cynologique International (FCI) has given five different grades from A to E, ranging from normal hip joint to severe dysplasia. Even in grade A, some changes can be observed [30]. The effectiveness of early detection can be verified by clinical and radiographic observation. Early identification and appropriate treatment have the potential to halt and even reverse the progression of the disease, thereby altering its pathogenesis [44].

In human pediatric medicine, various radiological measurements play a key role in cases that require surgical intervention. These measurements help human physicians assess the development of the acetabulum and its compatibility with the femoral head. By measuring various distances and angles on these images, it is possible to gain a detailed view of the development of the acetabulum and its relationship to the femoral head [27, 42]. This approach is not limited to human medicine but is equally applicable to veterinary medicine. While many aspects related to the proximal femur and acetabulum have been investigated in humans, research on these measurements in dogs has focused primarily on the Norberg angle, inclination, and anteversion angle [35]. It has been found that not only breed, but also the sex and body weight of the patient are important factors when measuring acetabular parameters [15].

In dogs, ventrodorsal radiographs of dysplastic hip joints may show abnormalities of the acetabulum, proximal femur, or a combination [22, 31]. Anatomic variations in the angle of inclination, anteversion, and instability or subluxation of the hip joint lead to an increase in the magnitude and changes in the direction of the force exerted on this joint. These changes in biomechanical balance cause increased muscle and ligament tension, as well as increased loading on articular cartilage [45]. This can lead to abnormal growth, reduction of the articular weight-bearing surface, cartilage overload, and the development of osteoarthritis [22, 45]. Nevertheless, the articular surfaces of the hip joint are loaded inhomogeneously. It has been shown that the healthy canine hip joint is physiologically incongruent [21].

Anatomy of the hip joint

The hip joint, also known as the coxofemoral joint is diarthrodial [3] consisting of the femoral head and acetabulum of the pelvis. The normal anatomical relationship between the acetabulum and femoral head provides stability and functionality of the joint. These structures are optimally developed in healthy dogs and provide an even load distribution [18]. The articular surfaces of the femoral head and acetabulum are almost identical in terms of surface area and radius of curvature [3]. The space, which is located between the ilium and the ischium, forms the base of the acetabulum. It begins to ossify 6–8 weeks after birth and facilitates fusion of the pelvic bones at this junction. Occasionally, a smaller *os coxa quartum*, which represents the apophysis, may develop, especially in dogs of larger breeds. The iliac bones fuse with the sacrum and femur and eventually fuse at the pubic symphysis [18]. It is further divided into the ventromedial fossa of the acetabulum, where the ligament of teres, also called the round ligament or ligament of the femoral head, exits. The articular cartilage makes up approximately two-thirds of the entire surface and is located dorsomedially. In animals, the femoral head and neck are inclined to the femoral diaphysis at an angle of 130–145 degrees and, in addition, are rotated anteriorly by 12–40 degrees [3].

Radiographic evaluation

X-rays have been essential in diagnostics of hip dysplasia since 1935 when dysplasia was first reported [5]. Using radiographic evaluation methods, various screening and breeding control programs have been developed to address the widespread occurrence of dysplasia in dogs. There is a need to quickly and accurately identify diseased animals so that selective breeding can be implemented [3]. Radiographs allow detailed visualization of the hip joint, assisting in the assessment of acetabulum development and femoral head position. Different X-ray projections provide different views of the hip joint, allowing for comprehensive evaluation and screening of patients for hip dysplasia. These projections help in identifying abnormalities, treatment planning and monitoring the progression or improvement of the condition [5].

Radiographic images of the pelvis include various positions. The lateral position is used as a routine pelvic image and is also useful for assessing hip luxations [4]. The extended ventrodorsal position is commonly used to evaluate the hip joints, but it is also valuable for visualizing degenerative changes and assessing femoral head overlap [4]. The frog position, a flexed ventrodorsal position, helps measure acetabulum depth, check the fit of the femoral head, and identify minor fractures of the femoral head and neck. The dorsal acetabular rim view position, a dorsoventral position with flexed hips, is used to assess acetabular depth and hip laxity. Lastly, the PennHIP position involves a series of stretched, compressed, and distracted dorsoventral positions using a specific distraction device to evaluate hip laxity. Special PennHIP training and certification are required, and images are submitted for PennHIP evaluation [26].

There is a paucity or absence of published research providing reference values for primary morphometric measurements of the hip joint in dogs that are of biomechanical significance and can be obtained via radiographic examination [22]. Significant differences between dog breeds have been observed, particularly due to the distinct body structures that characterize each breed [28, 34].

Fig. 1. Extended ventrodorsal position. The dog is reclining in a supine position with its knee joints and hind limbs fully extended, resulting in internal rotation of the knee joints (with the patella in a central position and the femoral condyles of equal size).

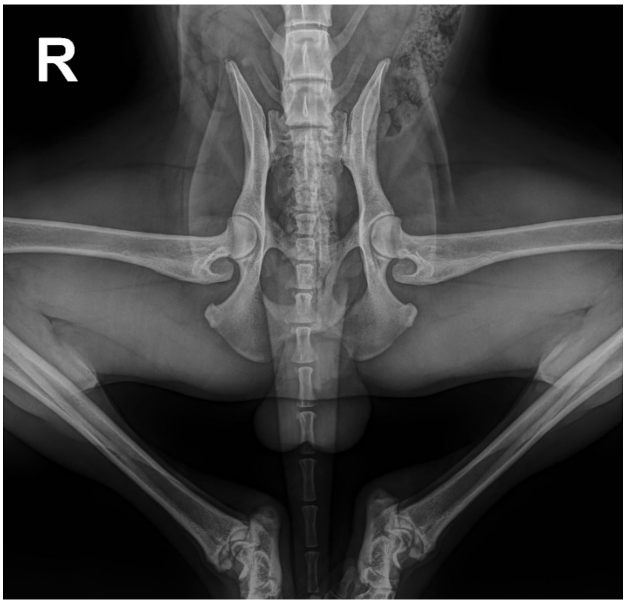

Fig. 2. Frog position. The dog is lying on its back with its hind legs bent outwards; the pelvis should be in a straight position; there should be no strain on the hip joint compared to the traditional ventrodorsal position.

Changes observed in the acetabulum

Acetabular index of depth to width – this measurement assesses the depth of the acetabulum [7]. St. Bernard and Bernese Mountain Dogs had the greatest relative acetabular depth, while Boxers and Labrador Retrievers had the shallowest and most open acetabulum. German Shepherds and Rottweilers had a slightly deeper and less open acetabulum than these breeds [35, 37]. In a study of Maltese and Shih-Tzu dogs, the acetabular index did not depend on any factor - age, sex, and breed [15].

Acetabular width (AW) is the distance measured from the acetabulum's lateral superior margin to the acetabulum's inferior margin [10]. Male Labrador Retriever dogs younger than 6 months of age tend to have higher AW values in cases of bilateral hip dysplasia compared to female dogs [17]. Similarly, these values were also higher in male Sivas Kangal dogs [34]. In addition, AW values were significantly elevated in cases of bilateral hip dysplasia [17]. In the study, AW measurements in Maltese and Shih-Tzu dogs were influenced by breed, sex, and body weight but not age. Male Shih-Tzu dogs showed higher AW values than Maltese [15].

Acetabular angle (AA) measures the inclination of the cranial margin of the acetabulum [25]. AA remains consistent despite pelvic rotation, tilt, and age. In cases of canine hip dysplasia (CHD), AA is significantly increased [17], and dogs that have an acetabular angle index greater than nine degrees should be excluded from breeding groups to limit the number of offspring affected by CHD [25]. Specifically, in cases where CHD was bilateral, AA was significantly higher compared to cases where CHD was unilateral. Furthermore, among dogs with bilateral CHD, males showed significantly higher AA values compared to females [17].

External acetabular angle (EAA) is derived from the horizontal to it´s external angle (HTE) and reflects the orientation of the roof of the acetabulum in the coronal plane. In healthy individuals, the HTE angle is usually 10° or less, but higher angles are common in cases of acetabular dysplasia [34].

The acetabular angle of retrotorsion (AAR) is an indicator of hip abnormality. It is a measurement of the depth of the acetabulum itself by connecting the point where the cranial and dorsal margins of the acetabulum meet with the maximum caudal extension of the acetabular notch. An AAR of 15° to 18° is considered typical for the hip joint.

The range of AAR values in the study for Leonberger's patellofemoral joint was 8° to 23° [8].

Acetabulum head index (AHI) measures the proportion of the femoral head surface that covers the acetabulum. Typical head coverage ranges from 70 % to 90 %, with an average of 90 % [9, 34]. In a group of dogs with a healthy hip joint, the AHI was significantly higher in males [17].

In addition to traditional ventrodorsal (VD) imaging, dorsal acetabular rim imaging of the acetabular rim and weight-bearing region of the acetabulum can also be used to assess the acetabular joint. This view is useful in the radiographic evaluation of hip dysplasia in dogs [23].

Changes observed in the femur

Femoral neck length and width (FNL and FNW) – FNL is determined as the distance between the centre of the femoral head and the centre of the base of the femoral neck, as previously determined to measure the cervicodiaphyseal angle. In an X-ray study on 82 femurs of different breeds of dogs, an average femoral neck length of 18.7 mm was found [28]. Measurements of head and femoral neck dimensions in humans were conducted, resulting in the derivation of the head and neck index. This index evaluates the general deformity of the proximal femur, particularly in relation to avascular necrosis with metaphyseal involvement. The typical value of this index in human anatomy is around 100 mm. A lower quotient indicates a higher degree of deformity compared to the opposite side of the hip joint [34, 42].

The neck-shaft angle (NSA) and the angle of femoral neck anteversion (FAV) are key assessments of the proximal femur. These measurements are extremely important when considering surgical intervention for hip dysplasia. The NSA reflects the relationship between the femoral neck and the shaft, while the FAV indicates the degree of femoral neck rotation. Cervico-diaphyseal angle is often used as a synonym for NSA, which also describes the angle between the axis of the femoral neck and the axis of the femoral diaphysis. In the study by Montavon et al. [24] values of 140.5° to 156.5° were measured. In the a study by Palierne on a diverse sample of dogs, the mean value of this angle was measured to be 140.9°, with a minimum value of 130.0° and a maximum value of 154.0° [28]. In another study by Kara et al. on a sample of healthy femurs of different breeds, the values were 146.24°, with bitches showing a smaller value than dogs [16]. In a sample of 8 dogs of medium to large breeds, the mean value was 129.6° [36]. Computed tomography measurements for medium to large breed dogs showed a mean femoral neck angle (FNA) of 147.50° [1].

Hip axis length (HAL) is the distance measured along the axis of the femoral neck, starting from the base of the greater tuberosity and extending to the inner edge of the pelvic bone. This measurement helps in assessing the geometry of the hip joint [11]. This value has greater sensitivity and specificity than bone mineral density for predicting fracture risk. This means that HAL is a more reliable predictor of fracture risk compared to conventional bone quality measurements [34]. HAL values were significantly higher in CHD, especially in male Sivas Kangal dogs [17, 35].

The mean FSC values of the femoral shaft cortex width were higher in the group of healthy males compared to the female group. However, in the group of dogs diagnosed with hip dysplasia, the trend was reversed with females showing significantly higher FSC values compared to males [17].

Trochanteric width (TW): there is a difference in TW values between males and females depending on their hip health status. Among dogs with healthy hip joints, males had significantly higher TW values compared to females [17, 35]. However, in cases of CHD in dogs, the trend was reversed, with females showing significantly higher TW values compared to males [17].

Femoral Inclination Angle (FIA) is crucial for the load transfer from the femur to the acetabulum. The importance of this angle lies in its role in determining how weight and forces are distributed in the hip joint, which is particularly important in conditions where joint stability is compromised [35]. A modified method based on the symmetrical axis, developed by Rumph and Hathcock, is used to plot the femoral neck and proximal femur axes. One circle is placed exactly at the femoral head. The other three circles are placed in the femoral neck, proximal, and medial femur so that they touch the border of the silhouette. Straight lines are drawn between the centres of these circles to draw the axis of the neck and the axis of the proximal femur [32, 35]. In a study by Sarierler, there were no significant overall differences in the angles of inclination between dysplastic and non-dysplastic dogs, but some breed-specific differences were observed. Specifically, Labrador Retriever and Doberman Pinscher, Anatolian Carabash, Doberman, Labrador and Sivas Kangal, Irish Setter, Golden Retriever, and German Shepherd showed significant inter-breed differences. In addition, analysis of femoral inclination angles in relation to age and sex revealed no significant differences between males and females or between younger and older dogs [31]. Higher FIA values were observed in congenital hip dysplasia [35]. This was confirmed in a study where the preoperative FIA in dysplastic breeds was 127.6° [29] as well as in a study by Madsen and Svalastoga [20]. The FIA was significantly higher in dogs with a healthy hip joint. In CHD, males had higher FIA values [17]. The association between FIA and femoral neck anteversion was confirmed. Additionally, dogs with a steep inclination angle had significantly greater femoral neck anteversion compared to dogs with a less steep inclination angle [20].

Percentage coverage of the femoral head (PC) is another indicator used to assess the hip joint. The hip joint is considered normal if the acetabulum covers 50 % or more of the femoral head [40]. In a group of dogs with dysplastic hips, the value was 36.9 [29]. PC varies significantly depending on gender and the presence of unilateral hip dysplasia. In dogs with healthy hip joints, males had significantly higher PC values compared to females. Conversely, in cases of unilateral CHD, female dogs showed significantly higher PC values compared to males [17]. PC ranged from 6.5 % to 79.9 % for Labrador Retrievers, from 5.7 % to 79.5 % for Rottweilers, from 8.3 % to 79.3 % for Golden Retrievers, and from 5.4 % to 83.7 % for German Shepherds [40].

Norberg angle (NA)

NA is defined by two straight lines emanating from the center of the femoral head. The first line is tangential to the craniolateral margin of the acetabulum and the second line connects the midpoints of the contralateral femoral heads [23]. NA greater than 105° is usually considered normal and indicates a stable hip joint. Angles less than 105° indicate hip laxity, characteristic of hip dysplasia, when the femoral head is not well seated in the acetabulum, suggesting potential instability or abnormal development of the hip joint [5]. This was confirmed in a study where dysplastic dog breeds had an NA value of 78.9° [29]. A certain NA value (e.g. 105°) may indicate high-quality (tight) hip joints in one breed, but lower-quality (looser) hip joints in another breed. Therefore, it is recommended to evaluate the NA of the hip joints of a particular dog as a percentage rating compared to the NA of other dogs of the same breed. This provides a more accurate picture of the quality of a particular dog's hip joints within its breed [6]. NA ranged between 67.4° and 124.4° for Labrador Retrievers, 59.7° and 128.6° for Rottweilers, 70.2° and 119.4° for Golden Retrievers, and 55.3° and 121.3° for German Shepherds [40]. In a study for the Leonberger breed, a range of NA from 82° to 120° was found [8].

Distraction Index (DI) and Subluxation Index (SI)

Distraction index (DI) and subluxation index (SI) are used to measure hip laxity using ventrodorsal distraction imaging, which is performed when a special distractor is used to separate the femoral head from the acetabulum. DI provides an accurate numerical determination of laxity and is part of the PennHIP method, which is performed under general anesthesia or deep sedation. This test includes three different views of the hip joint: a standard ventrodorsal image to detect osteoarthritis and compression and distraction images to calculate DI [13]. Unlike qualitative assessment methods that use descriptive ratings (e.g., excellent, good, fair), the PennHIP provides quantitative data on joint laxity [38].

A significant advantage of the PennHIP method is that it allows for reliable assessment of young dogs as young as 16 weeks and accurately predicts the risk of developing osteoarthritis later in life [13]. In studies on American Bulldogs, Bernese Mountain Dogs, Newfoundland dogs, and Standard Poodles, DI was the most significant predictor for the development of osteoarthritic changes associated with hip dysplasia, with weight and age of the dogs also playing a significant role [33].

Other studies, such as those of Taroni et al. and Klever et al., revealed that dogs classified as phenotypically normal by the Orthopedic Foundation for Animal (OFA) or FCI may have exhibited significant hip laxity that was detected by distraction radiography. These results suggest that traditional OFA or FCI scoring based on standard ventrodorsal radiographs may underestimate the risk of osteoarthritis [39, 19]. A study found that even phenotypically healthy dogs by OFA may have significant joint laxity as detected by DI, which has been shown to be a more effective tool for identifying hip dysplasia than the NA. Thus, DI may be a valuable adjunct to standard scoring in hip dysplasia screening. These findings highlight that current methods may slow progress in dysplasia reduction through breeding [39].

CONCLUSIONS

The evaluation of the morphometric parameters of the hip joint in the dog is usually focused on the evaluation of the radiological parameters of the proximal femur and acetabulum. There are many publications that track changes in the acetabulum and proximal femur; however, significant differences in the tracking of these radiological parameters can be observed within individual studies. These differences often result from a variety of methods for assessing and interpreting measured data, underscoring the need for standardized procedures for monitoring these key aspects of the hip joint. For surgeries such as hip replacement, surgeons should consider breed-specific acetabular values to achieve optimal results. Nevertheless, further research is needed to see if there is a correlation between these parameters and various hip disorders, as most of the research done so far has been done on a small number of cases.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The raw data of this article will be made available by the authors, without undue reservation.

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AUTHORS CONTRIBUTIONS

Gabriela Kacková conceptualized the review, conducted the literature search, and drafted the manuscript. Slavomír Horňák proposed the topic and contributed to the critical revision of the manuscript. Mária Figurová acquired and processed the radiographic images used in the review. Nela Vargová assisted with literature selection and manuscript editing. Veronika Tauberová contributed to data interpretation and final manuscript review.

GENERATIVE AI STATEMENT

The authors declare that no Gen AI was used in the creation of this manuscript.

REFERENCES

1. **Al Aiyan, A., Richardson, K., Manchi, G., Plendl, J., Brunnberg, L., 2019:** Measurement of the femoral neck angle in medium and large dog breeds using computed tomography. *Acta Vet. Hung.*, 67, 1, 22–33. DOI: 10.1556/004.2019.003.
2. **Alves-Pimenta, S., Santana, A., Martins, J., Colaço, B., Gonçalves, L., Ginja, M., 2020:** Distraction index measurement on the dog's hip joint using a dedicated software. *Arq. Bras. Med. Vet. Zootec.*, 72, 4, 1241–1247. DOI: 10.1590/1678-4162-11692.
3. **Arthurs, G., Brown, G., Pettitt, R., British Small Animal Veterinary Association, ed., 2018:** *BSAVA manual of canine and feline musculoskeletal disorders: A Practical guide to lameness and joint disease*. Second edition. Quedgeley: British Small Animal Veterinary Association, 504 pp.
4. **Berry, C. R., Nelson, N., Winter, M. D., 2023:** *Atlas of small animal diagnostic imaging*. Hoboken, NJ: Wiley, 820 pp.
5. **Butler, J. R., Gambino, J., 2017:** Canine Hip Dysplasia: Diagnostic Imaging. *Vet. Clin. Small Anim. Pract.*, 47, 4, 777–793. DOI: 10.1016/j.cvsm.2017.02.002.
6. **Comhaire, F. H., Schoonjans, F. A., 2011:** Canine Hip Dyslasia: The significance of the Norberg angle for healthy breeding. *J. of Small Anim. Pract.*, 52, 10, 536–542. DOI: 10.1111/j.1748-5827.2011.01105.x.
7. **Delaunay, S., Dussault, R. G., Kaplan, P. A., Alford, B. A., 1997:** Radiographic measurements of dysplastic adult hips. *Skeletal Radiol.*, 26, 2, 75–81. DOI: 10.1007/s002560050197.
8. **Doskarova, B., Kyllar, M., Paral, V., 2010:** Morphometric assessment of the canine hip joint using the acetabular angle of retrotorsion. *Vet. Comp. Orthop. Traumatol.*, 23, 5, 326–531. DOI: 10.3415/VCOT-09-08-0086.

9. **Dueland, D. J., 1980**: Femoral torsion and its possible relationship to canine hip dysplasia. *Vet. Surg.*, 9, 48.
10. **Edwards, K., Leyland, K.M., Sanchez-Santos, M.T., Arden, C.P., Spector, T.D., Nelson, A.E., et al., 2019:** Differences between race and sex in measures of hip morphology: a population-based comparative study. *Osteoarthr. Cartil.*, 28, 2, 189–200. DOI: 10.1016/j.joca.2019.10.014.
11. **Faulkner, K. G., Mcclung, M., Cummings, S. R., 1994:** Automated evaluation of hip axis length for predicting hip fracture. *J. Bone Miner. Res.,* 9, 7, 1065–1070. DOI: 10.1002/jbmr.5650090714.
12. **Flückiger, M., 2007:** Scoring radiographs for canine hip dysplasia -The big three organisations in the world. *Eur. J. Companion Anim. Pract*., 17, 2, 135–140.
13. **Guilliard, M., 2014:** The PennHIP method of predicting canine hip dysplasia. *InPract.*, *36*, 2, 66-74. DOI: 10.1136/inp.f7486.
14. **Jaffar, M., Murlimanju, B.V., Saralaya, V.V., Prabhu, L.V., Prashanth, K.U., Krishnamurthy, A., 2012**: Bone Morphometry. *Bratisl. Med. J*., 113, 11, 673–675. DOI: 10.4149/BLL_2012_152.
15. **Kanokporn, K., Klaengkaew, A., Thanaboonnipat, CH., Damri, D. K. S., Choisunirachon, N., 2021:** Comparison of radiographic and computed tomographic acetabular index in small-breed dogs: a preliminary study using Maltese and Shih Tzu. *J. Vet. Sci.,* 22, 4, 58. DOI: 10.4142/jvs.2021.22.e58.
16. **Kara, M. E., Sevil-Kilimci, F., Dilek, Ö. G., Onar, V., 2018:** Proximal and distal alignment of normal canine femurs: A morphometric analysis. *Ann. Anat.,* 217, 125–128. DOI: 10.1016/j.aanat.2018.02.006.
17. **Kataru, J. M. R., Podarala, V., Venkata, S. K. R., Mukku, S. L., Jampala, V. S., 2023:** Morphometry of normal hip joint and dysplastic hip joint in young Labrador retriever dogs – a study. *Indian J. Canine Pract.*, 15, 1 ,73–76. DOI: 10.29005/IJCP.2023.15.1.073-076.
18. **Kirberger, R. M., Fintan J. M., 2016:** *BSAVA Manual of canine and feline musculoskeletal maging.* British Small Animal Veterinary Association, 408 pp.
19. **Klever, J., Brühschwein, A., Meyer-Lindenberg, A., 2020:** Distraction index and Norberg angle to distinguish dysplastic and non-dysplastic hips based on FCI score. *Tierarztl. Prax. Ausg. K: Kleintiere Heimtiere*, *48,* 4, 250-258. DOI: 10.1055/a-1213-4574
20. **Madsen, J. S., a E. Svalastoga., 1994:** Inclination and anteversion of *Collum Femoris* in hip dysplasia and coxarthritis. *Acta Vet. Scand.*, 35, 2, 115–119. DOI: 10.1186/BF03548337.
21. **Maierl, J., Lieser, B., Böttcher, P., Liebich, H. G., 2005:** Functional anatomy and biomechanics of the canine hip joint. *Anat, Histol, Embryol.*, 34, s1, 32–32. DOI: 10.1111/j.1439-0264.2005.00669_72.x.
22. **Martins, J., Ferreira, A. J., Ginja M. M., 2012:** Morphometric Aassessment of the hip joint in the Estrela Mountain dog breed. *Vet. Comp. Orthop. Traumatol.*, 25, 3, 202–210. DOI: 10.3415/VCOT-11-07-0101.
23. **Meomartino, L., Fatone, G., Potena, A., Brunetti, A., 2002:** Morphometric assessment of the canine hip joint using the dorsal acetabular rim view and the centre-edge angel. *J. Small Anim. Pract*., 43, 1, 2–6. DOI: 10.1111/j.1748-5827.2002.tb00001.x.
24. **Montavon, P. M., Hohn, R. B., Olmstead, M. L., Rudy, R. L., 1985:** Inclination and anteversion angles of the femoral head and neck in the dog evaluation of a standard method of measurement. *Vet. Surg.,* 14, 4, 277–282. DOI: 10.1111/j.1532-950X.1985.tb00883.x.
25. **Mostafa, A. A., Nahla, M. A., Ali, K. M., Berry, C.R., 2022:** Modified FCI (Féderation Cynologique Internationale) Scoring of the coxofemoral joint in Labrador Retrievers without and with hip dysplasia. *Front. Vet. Sci.*, 9. DOI: 10.3389/fvets.2022.800237.
26. **Muhlbauer, M. C., Kneller, S. K., 2013:** *Radiography of the dog and cat: guide to making and interpreting radiographs*. Ames, Iowa: Wiley-Blackwell, 497 pp.
27. **Önal, V., Metin T. A., Durum P. Y., 2023:** Morphometric assessment of the hip joint in children aged 2–13 years. *Clin. Anat*., 36, 6, 926–936. DOI: 10.1002/ca.24061.
28. **Palierne, S., Asimus, E., Mathon, D., Meynaud-Collard, P., Autefage, A., 2006:** Geometric analysis of the proximal femur in a diverse sample of dogs. *Res. Vet. Sci.,* 80, 3, 243–252. DOI: 10.1016/j.rvsc.2005.07.010.
29. **Pinna, S., Enrico P., Fabio, C., 2013:** Effects of intertrochanteric varus osteotomy on Norberg angle and percent coverage of the femoral head in displastic dogs. *J. Vet. Sci.,* 14, 2, 185–191. DOI: 10.4142/jvs.2013.14.2.185.
30. **Pinna, S., Vezzoni, A., Di Benedetto, M., Lambertini, C., Tassani, C. P., 2023:** Characterization of FCI (Fédération Cynologique Internationale) grades for hip dysplasia in five dog breeds. *Animals.* 13, 13, 2212. DOI: 10.3390/ani13132212.
31. **Prieur, W. D., 1998:** *Current Techniques in Small Animal Surgery.* Teton NewMedia, United States, 1183 pp.
32. **Rumph, P. F., Hathcock, J. T., 1990:** A Symmetric axis-based method for measuring the projected femoral an-

gle of inclination in dogs. *Vet. Surg.,* 19, 5, 328–333. DOI: 10.1111/j.1532-950X.1990.tb01200.x.

33. **Runge, J. J., Kelly, S. P., Gregor, T. P., Kotwal, S., 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.*, *51*, 5, 264-269. DOI:10.1111/j.1748-5827.2010.00937.x.
34. **Sarierler, M., 2004**: Comparison of femoral inclination angle measurements in dysplastic and nondysplastic dogs of different breeds. *Acta Vet. Hung.,* 52, 2, 245–252. DOI: 10.1556/avet.52.2004.2.13.
35. **Sarierler, M., Tatli, Z. B., Akin, I., Yaygingül, R., DeriNcegöz, O. Ö., 2017:** Radiographic examination of hip joint geometry in healthy Sivas Kangal dogs. *Turk. J. Vet. Anim. Sci.,* 41, 1, 85–92. DOI: 10.3906/vet-1602-10.
36. **Savio, G., Baroni, T., Concheri, G., Baroni, E., Meneghello, R., Longo, F., Isola, M., 2016:** Computation of femoral canine morphometric parameters in three-dimensional geometrical models. *Vet. Surg.,* 45, 8, 987–895. DOI: 10.1111/vsu.12550.
37. **Scartazzini, R., 1972:** A radiologic study of normal and dysplastic hip joints in six breeds of large dogs. *Acta Radiol. Diagn.,* 13, 319, 183–85. DOI: 10.1177/0284185172013S31935.
38. **Smith, G., 2000:** Summary of PennHIP Research. *Health*, 06-02.
39. **Taroni, M., Genevois, J. P., Viguier, E., Pillard, P., Livet, V., Cachon, T., Carozzo, C., 2018:** Comparison of early measurements of the distraction index, Norberg Angle on distracted view and the official radiographic evaluation of the hips of 215 dogs from two guide dog training schools. *Vet. Comp. Orthop. Traumatol.*, *31*, 6, 445-451. DOI: 10.1055/s-0038-1668087.
40. **Tomlinson, J. L., Johnson. J.C., 2000:** Quantification of measurement of femoral head coverage and Norberg angle within and among four breeds of dogs. *Am. J. Vet. Res.,* 61, 12, 1492–1500. DOI: 10.2460/ajvr.2000.61.1492.
41. **Tönnis, D., 2012:** *Congenital dysplasia and dislocation of the hip in children and adults*. Springer Science & Business Media, Heidelberg, 538pp. DOI: 10.1007/978-3-642-71038-4.
42. **Ünlü, S., Çatma, M. F., Bilgetekin, Y. G., 2014:** Pediatrik kalça sorunlarında görüntüleme yöntemleri. *Totbid Derg.*, *13*, 390-395. DOI: 10.14292/totbid.dergisi.2014.44.
43. **Vezzoni, A., 2008:** Definition and clinical diagnosis of Canine Hip Dysplasia; early diagnosis and treatment options. *Eur. J. Companion Anim. Pract.,* 17, 2, 126-132.
44. **Vezzoni, A., Dravelli, G., Corbari, A., Lorenzi, M. D., Cirla, A., Tranquillo, V.,2005:** Early diagnosis of canine hip dysplasia. *J. EJCAP.,* 15,1.
45. **Weigel, J. P., Wasserman, J.F., 1992:** Biomechanics of the normal and abnormal hip joint. *Vet. Clin. North Am.: Small Anim. Pract*., 22, 3, 513–528. DOI: 10.1016/S0195-5616(92)50052-3.