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The ligaments of the canine hip joint revisited

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With 3 tables and 7 figures

Short title: Canine hip joint ligaments

Abstract

Numerous conventional anatomical textbooks describe the canine hip joint, but many contradictions, in particular regarding the ligament of the femoral head, are present. This paper presents a brief overview of the different literature descriptions. These are compared with own observations that have resulted in a revised description of the anatomy of the ligament of the femoral head in the dog. To this purpose, the hip joints of 41 dogs, euthanized for reasons not related to this study and devoid of lesions related to hip joint pathology, were examined. It was observed that the ligament of the femoral head is not a single structure that attaches only to the acetabular fossa, as generally accepted, but it also connects to the transverse acetabular ligament and is complemented by a strong accessory ligament that courses in caudal direction to attach in the elongation of the acetabular notch that extends on the cranioventral surface of the body of the ischium. The description of this accessory ligament in conventional anatomical handbooks is incomplete. This description of the accessory ligament of the femoral head could support the research unravelling the etiopathogenesis of hip instability.

Key words: Canine hip joint; Acetabulum; Ligament of the femoral head; Transverse ligament; Hip dysplasia

Introduction

The canine hip joint (*Articulatio coxae*) is of major clinical importance since hip dysplasia is a common orthopaedic disorder in the dog (Ginja et al., 2010). As a result, all consulted conventional anatomical handbooks cover the anatomy of the hip joint. However, the ligament of the femoral head, designated in official nomenclature as *Ligamentum capitis ossis femoris*, a term to be preferred above the term round ligament or *Ligamentum teres femoris* (World Association of Veterinary Anatomists, 2012), is described ambiguously. The most straightforward descriptions reflect the general knowledge that in domestic mammals this ligament is located inside the joint capsule and connects the acetabular fossa (*Fossa acetabuli*) with the fovea of the femoral head (*Fovea capitis ossis femoris*) (Zietzschmann, 1974; Sisson, 1975; Popesko, 1982; Anderson and Anderson, 1994; Liebich and König, 2001; Salomon, 2005; Done et al., 2009; Dyce et al., 2010). Other authors provide more detailed descriptions. According to Nickel et al. (1986) and Liebich et al. (2004) the ligament of the femoral head originates in the acetabular fossa and continues through the acetabular notch (*Incisura acetabuli*) to insert in the fovea of the femoral head. Evans (1993) and Evans and deLahunta (1996) state that branches of the ligament of the femoral head blend with the transverse acetabular ligament (*Ligamentum transversum acetabuli*), resulting in a broad, fan-shaped attachment to the acetabulum. Adams (2004) also described such fan-shaped formation of the acetabular attachment. Barone (2000) mentions an accessory ligament, which runs in the acetabular notch towards the transverse acetabular ligament and leaves the acetabular notch at the cranial border. In contrast, Budras and Reese (2002) illustrate that the

ligament of the femoral head proceeds in caudal direction through the acetabular notch to attach to the pelvis outside the hip joint.

From this concise literature review it might be clear that many different descriptions, resulting in contradictions and ambiguity, are present in literature. The ligament of the femoral head is indeed a complex structure, as evidenced recently in a comparative study by Canillas et al. (2011), who demonstrated that in various species, including amphibians, reptiles, birds and mammals, this ligament shows most notable changes not only in its insertions but also in the number of its bundles, while a fibrocartilaginous meniscoid structure is present in the hip joint of various mammals including rats and cats. Since the inaccurate descriptions of the complex ligament of the femoral head could hamper the unravelling of the etiopathogenesis of canine hip joint pathologies, an anatomical study was performed revisiting the canine hip joint. The aim of this paper is to describe the anatomy of the ligament of the femoral head in great detail and to present morphometric data on this ligament in different dog breeds.

Materials and methods

Animals

Forty-one dogs, euthanized for reasons other than this study and devoid of lesions related to hip joint pathology, were included. Since the animals originated from different Flemish animal shelters, no information of age was available. However, all dogs had permanent dentition and appeared adult on visual inspection. Breed and weight are presented in Table 1.

Dissection of the hip joint

The dogs were positioned in dorsal recumbency allowing the dissection of their hip joints via a ventromedial approach. After removal of the joint capsule, the ligament of the femoral head became visible and could be studied anatomically and morphometrically. The transverse acetabular ligament was subsequently removed. Finally, the ligament of the femoral head was meticulously excised to allow further morphometric analysis.

Morphometric analysis

The length of the ligament of the femoral head from its origin in the fovea of the femoral head to its attachment in the acetabular fossa as well as the length of any accessory ligament was determined using digital sliding callipers. In addition, the ligament of the femoral head was excised and weighed, and its volume was determined by means of the water displacement method. The correlation between the mean weights of the examined dog breeds and the mean weights, volumes and lengths of their ligaments of the femoral head as well as the lengths of the their accessory ligaments were calculated.

Preparation of an arthrologic specimen

An arthrologic specimen was prepared using a representative left hip joint. This specimen contained the left femur and hip bone (*Os coxae*) connected by the ligament of the femoral head and any additional ligaments under study. The majority of soft tissues located outside the joint capsule were removed manually. The smaller tissue remnants were then macerated by immersion in sodium hypochlorite 42° (VWR International N.V., Leuven, Belgium) for approximately 15 minutes. Finally, the joint capsule was removed.

After rinsing the arthrologic specimen with cold tap water it was bleached by immersion in 10% hydrogen peroxide (UNIVAR Benelux N.V., Brussels, Belgium) for three days. The specimen was then rinsed again and dried in a vented hood.

Results

Anatomy of the ligament of the femoral head

The ligament of the femoral head originated from the fovea of the femoral head and contained a variable amount of adipose tissue. Its lateral segment, which inserted on the fovea of the femoral head, was cylindrical and consisted of a single strand. The ligament fanned out on its course towards the acetabulum to form multiple, partly fused fascicles that attached to the acetabular fossa (Fig. 1), to the dorsal border of the transverse acetabular ligament (Figs. 1 and 2) and to the origin of the caudal elongation of the acetabular notch that extends on the cranioventral surface of the body of the ischium, without breaching the acetabular contour nor the joint capsule (Fig. 3).

In all examined hip joints, an additional strong strand branched off from the ligament of the femoral head and coursed in caudal direction through the acetabular notch. This accessory ligament broke through the joint capsule to fill the entire caudal elongation of the acetabular notch. As such, it was easily recognized as a separate ligament. In most cases, the accessory ligament was attached to the transverse acetabular ligament when it crossed the latter (Figs. 4 and 5).

In five dogs, the accessory ligament of either hip joint ran to and inserted on the cranial extremity of the transverse acetabular ligament. It then continued in the acetabular notch to attach to its caudal elongation. The accessory ligament was located parallel and

dorsomedial to the transverse acetabular ligament, but could be separated from the latter (Fig. 5).

In one dog the accessory ligament of either hip joint could be distinctly separated from the transverse acetabular ligament, since the ligament of the femoral head showed no attachment to the transverse acetabular ligament (Fig. 6).

The arthrologic specimen that was prepared from a representative joint is shown in Fig. 7. The specimen shows the typical branching pattern of the ligament of the femoral head, including the accessory ligament which crosses the transverse acetabular ligament dorsally, courses caudally in the groove formed by the caudal elongation of the acetabular notch and attaches both in this bony groove and on the adjacent cranioventral surface of the body of the ischium.

Morphometric characteristics of the ligaments of the femoral head

The weights, volumes and lengths of the ligaments of the femoral head in the various breeds are shown in Table 2. The length of the accessory ligament, measured from its origin from the ligament of the femoral head to its attachment on the ischium, is presented in Table 3. The correlation coefficients (r) were the following: r(body weight, ligament weight) = 0.91, r(body weight, ligament volume) = 0.91, r(body weight, ligament length) = 0.45, r(body weight, accessory ligament length) = 0.66.

Discussion

The typical configuration of the ligament of the femoral head, as presented in Fig. 7, has not been described previously. In all but one of the examined dogs, the ligament attached

to the transverse acetabular ligament before inserting in the acetabular fossa. Such attachment has only been described by Evans (1993), while it was observed in the vast majority of the dogs examined in the present study. The results further show that the common English term for the ligament of the femoral head, i.e. round ligament, is confusing since the ligament is only cylindrical at its origin in the fovea of the femoral head and fans out to form multiple fascicules. The presence of an accessory ligament branching off from the ligament of the femoral head and running in caudal direction to attach to the pelvis outside the joint cavity has previously been illustrated solely by Budras and Reese (2002).

Such an accessory ligament branching off from the ligament of the femoral head is not mentioned in the *Nomina Anatomica Veterinaria* (World Association of Veterinary Anatomists, 2012) and is therefore still innominate. Providing a name for this structure would omit the need for extensive descriptions when referring to it. The *Nomina Anatomica Veterinaria* (World Association of Veterinary Anatomists, 2012) stipulates that new terms should be as short and simple as possible, but also instructive and descriptive. A potential name could be *Ligamentum accessorium capitis ossis femoris*, which is very descriptive in nature. However, this term should not be confused with the *Ligamentum accessorium ossis femoris* that is only present in the horse and rabbit and connects the fovea of the femoral head with the attachment of the straight abdominal muscle to the prepubic tendon.

The ligament of the femoral head contained a variable amount of adipose tissue, which might have interfered with the morphometric analysis since it was difficult to completely remove the smaller fatty remnants. Only a few publications present data about the volume

of the ligament of the femoral head in various breeds. Values ranging from 0.53 to 0.62 cm³ have been published for the Labrador Retriever (Lust et al., 1980a; Lust and Summers, 1981; Burton-Wurster et al., 1999). Mande and co-workers (2003) reported a mean volume of 0.82 ml in the German Shepherd Dog. In the present study, values of 0.59 cm³ and 0.90 m³ were measured in the Labrador Retriever and German Shepherd Dog, respectively. Our values are thus comparable with literature data, although it is not clear whether the accessory ligament of the femoral head was taken into account in the cited studies. It is not surprising that the weight and volume of the ligament of the femoral head correlate very well with the body weight ($r = 0.91$). In contrast, the length of the ligament of the femoral head is far less positively correlated to body weight ($r = 0.45$). The linear increase in the distance between the femoral head and the acetabular fossa is not pronounced since widening of the joint cavity negatively affects joint stability (Lust et al., 1980b).

A stronger correlation is present between the length of the accessory ligament and the body weight ($r = 0.66$). The larger the breed, the longer is the accessory ligament. However, since the accessory ligament inserts on the caudal elongation of the acetabular notch that extends on the cranioventral side of the body of the ischium, its length is more specifically related with pelvic length. The effect of age on the morphometry of the ligaments of the hip joint was not determined in the present study since no data about the ages of the dogs were available. However, since all dogs had a permanent dentition and appeared fully-grown, they were considered to be adults.

Detailed anatomical knowledge of the ligaments associated with the hip joint is important when studying the functionality of the articulation. Although the ligament of the femoral

head is a well-known structure, its role of in the etiopathogenesis of canine hip dysplasia is still to be elucidated. Arthroscopic examination of young dogs with hip dysplasia has revealed partial or complete rupture of this ligament in 81% and 7% of cases, respectively (Holsworth et al., 2005). A significant hypertrophy of the ligament of the femoral head, characterized by elongation and thickening, has been observed in experimental cases of hip dysplasia in growing dogs (Schoenecker et al., 1984). These two studies illustrate that elongation of the ligament of the femoral head is associated with hip dysplasia. It is, however, not known whether the elongation of the ligament of the femoral head is the primary cause or a secondary effect of the developing pathology. It is hypothesized that laxity of the fibrocartilagenous structures associated with the hip joint results in hip instability which further develops to hip dysplasia.

Many authors agree that primary or secondary osteoarthritis also affects the integrity of the ligament of the femoral head and might increase its volume (Lust et al., 1980; Lust and Summers, 1981; Lust, 1997; Burton-Wurster et al., 1999; Clements et al., 2006). Other reports, however, are contradictory (Mande et al., 2003).

Hip luxation as often seen in traffic accidents is another pathology that might affect the ligaments of the canine hip joint (Jones, 1985). Since the ligament of the femoral head is rather elastic, it can herewith elongate and potentially rupture (Salomon, 2005; Dyce et al., 2010).

In analogy to the ligament of the femoral head, the role of the accessory ligament in the biomechanical functioning of the hip joint is still enigmatic. It is hypothesized that the articular structures of the hip have further developed during evolution to cope with the more complex movements of the hip joint in higher species. Indeed, in amphibians and

reptiles, the ligament of the femoral head is formed by a mere reinforcement of the dorsal side of the joint capsule, while it appears first as a typical structure in birds (Canillas et al., 2011). Furthermore, the number of fascicles of the ligament of the femoral head is associated with the rotary movement of the hip (Canillas et al., 2011). As a result, it is possible that the accessory ligament of the femoral head represents a further reinforcement of the hip joint. Whether an underdeveloped accessory ligament lies at the basis of hip laxity and dysplasia should be examined in future studies.

Conclusions

This work demonstrates that a strong accessory ligament is present in the canine hip joint in addition to the well-known ligament of the femoral head. The variable representations of the ligaments associated with the canine hip joint should be taken into account when examining the hip joint by medical imaging or macroscopic inspection during surgery. The detailed data presented here can be valuable in future studies unravelling the etiopathogenesis of hip dysplasia and allow for using the appearance of the ligaments as a diagnostic parameter.

Conflict of interest statement

None declared.

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Tables

Table 1. Breed and weight distribution of the examined dogs

Breed	Number of dogs examined	Mean weight $\pm$ standard deviation (range) in kg
American Staffordshire Terrier	5	24.8 $\pm$ 4.1 (20.5 – 31.5)
Beauceron	1	32.0
Belgian Malinois	1	20.0
Belgian Tervuren	1	35.0
Berner Sennen	1	32.0
Cairn Terrier	1	9.0
English Bulldog	1	23.5
English Cocker Spaniel	1	20.0
German Shepherd Dog	3	29.7 $\pm$ 1.8 (28.0 – 31.5)
Golden Retriever	1	37.0
Groenendaler	2	31.5 $\pm$ 4.2 (28.5 – 34.5)
Jack Russell Terrier	6	8.1 $\pm$ 2.1 (4.5 – 10.5)
Labrador Retriever	3	26.5 $\pm$ 0.9 (25.5 – 27.0)
Miniature Pinscher	1	10.0
Mongrel	10	16.1 $\pm$ 10.1 (7.0 – 32.0)
Rottweiler	3	38.5 $\pm$ 7.4 (33.5 – 47.0)

Table 2. Weight, volume and length of the ligament of the femoral head in the examined dog breeds

Breed	Number of joints examined	Mean weight $\pm$ standard deviation (range) in g	Mean volume $\pm$ standard deviation (range) in cm ³	Mean length $\pm$ standard deviation (range) in mm
American Staffordshire Terrier	10	0.72 $\pm$ 0.09 (0.60 – 0.90)	0.63 $\pm$ 0.10 (0.45 – 0.80)	15.08 $\pm$ 3.27 (8.92 – 19.14)
Beauceron	2	1.07 $\pm$ 0.09 (1.00 – 1.13)	0.99 $\pm$ 0.01 (0.98 – 0.99)	14.90 $\pm$ 0.53 (14.52 – 15.27)
Belgian Malinois	1	0.72	0.70	12.76
Belgian Tervuren	1	1.46	1.38	12.55
Berner Sennen	2	1.12 $\pm$ 0.07 (1.07 – 1.17)	1.01 $\pm$ 0.16 (0.90 – 1.12)	13.97 $\pm$ 0.18 (13.84 – 14.10)
Cairn Terrier	2	0.25 $\pm$ 0.04 (0.22 – 0.27)	-	-
English Bulldog	1	0.41	0.38	-
English Cocker Spaniel	2	0.39 $\pm$ 0.04 (0.36 – 0.41)	0.31 $\pm$ 0.01 (0.30 – 0.32)	17.14 $\pm$ 6.14 (12.80 – 21.48)
German Shepherd Dog	6	1.00 $\pm$ 0.13 (0.79 – 1.17)	0.90 $\pm$ 0.14 (0.70 – 1.10)	14.34 $\pm$ 1.19 (13.03 – 15.90)
Golden Retriever	2	0.93 $\pm$ 0.01 (0.92 – 0.94)	0.99 $\pm$ 0.01 (0.98 – 1.00)	15.06 $\pm$ 1.80 (13.78 – 16.33)
Groenendaler	4	0.94 $\pm$ 0.29 (0.70 – 1.33)	0.79 $\pm$ 0.23 (0.60 – 1.10)	14.47 $\pm$ 1.17 (13.64 – 15.30)
Jack Russell Terrier	10	0.19 $\pm$ 0.08 (0.09 – 0.33)	0.16 $\pm$ 0.05 (0.08 – 0.24)	11.06 $\pm$ 3.20 (7.24 – 18.03)
Labrador Retriever	5	0.63 $\pm$ 0.10 (0.51 – 0.76)	0.59 $\pm$ 0.08 (0.50 – 0.70)	16.46 $\pm$ 3.00 (12.22 – 18.67)
Miniature Pinscher	1	0.16	0.10	-
Mongrel	17	0.52 $\pm$ 0.35 (0.18 – 1.10)	0.43 $\pm$ 0.31 (0.10 – 1.00)	12.70 $\pm$ 4.37 (6.98 – 19.69)
Rottweiler	6	1.20 $\pm$ 0.44 (0.82 – 1.79)	1.13 $\pm$ 0.37 (0.80 – 1.62)	16.15 $\pm$ 5.67 (9.62 – 23.70)

Table 3. Length of the accessory ligament of the femoral head in the examined dog breeds, from its branching origin on the ligament of the femoral head to its attachment on the pelvis

Breed	Number of joints examined	Mean length $\pm$ standard deviation (range) in mm
American Staffordshire Terrier	10	13.37 ± 3.11 (8.70 – 18.22)
Beauceron	2	15.25 ± 0.16 (15.13 – 15.36)
Belgian Malinois	1	10.37
Belgian Tervuren	1	15.23
Berner Sennen	2	14.62 ± 1.04 (13.88 – 15.35)
English Bulldog	1	13.38
English Cocker Spaniel	2	11.86 ± 1.41 (10.86 – 12.85)
German Shepherd Dog	6	17.19 ± 2.44 (12.55 – 19.12)
Golden Retriever	2	10.55 ± 0.94 (9.88 – 11.21)
Groenendaler	4	13.69 ± 0.75 (12.72 – 14.56)
Jack Russell Terrier	7	9.15 ± 2.87 (4.47 – 12.62)
Labrador Retriever	4	11.65 ± 1.45 (9.50 – 12.58)
Mongrel	15	12.35 ± 3.17 (8.03 – 18.09)
Rottweiler	6	17.13 ± 1.83 (15.43 – 19.85)

Figures

Fig. 1. Cranioventral view of a left canine hip joint showing the branched, fan-shaped ligament of the femoral head (asterisks) originating on the head of the femur (a) and attaching to the acetabulum (b) and the transverse acetabular ligament (c).

Fig. 2. Lateroventral view of a left canine hip joint, formed between the femoral head (a) and the acetabulum (b), demonstrating the strand of the ligament of the femoral head (asterisk) that attaches to the transverse acetabular ligament (c). The latter ligament has been transected at its cranial insertion and is retracted by means of a forceps.

Fig. 3. Lateral view of a left canine acetabulum showing the major strand (a) of the ligament of the femoral head attaching to the acetabular fossa, and an additional strand (arrow) coursing in caudal direction between the transverse acetabular ligament (b) and the caudoventral border of the acetabulum (c).

Fig. 4. Caudoventral view of a left canine hip joint. The ligament of the femoral head (asterisk) connects the head of the femur (a) not only with the acetabulum (b), but also with the transverse acetabular ligament (c). The forceps indicates the caudal part of the accessory ligament of the femoral head that, after crossing the transverse acetabular ligament dorsally, courses in caudal direction towards the cranioventral surface of the body of the ischium.

Fig. 5. Ventral views of a left canine hip joint showing the attachment of the femoral head (a) to the acetabulum (b). Fig. 5A: The accessory ligament of the femoral head crosses the cranial attachment (asterisk) of the transverse acetabular ligament (c) dorsally and continues caudally outside the acetabulum (arrow). Fig. 5B: Resection of the transverse acetabular ligament demonstrates that the accessory ligament inserts to the cranial attachment site of the transverse acetabular ligament (arrowhead) and continues caudally in the acetabular notch (arrow) to attach to the caudal elongation of the latter structure on the cranioventral surface of the body of the ischium.

Fig. 6. Ventral view of a left canine hip joint, after removal of the transverse acetabular ligament, showing the ligament of the femoral head (asterisk) which connects the femoral head (a) with the acetabulum (b), and the accessory ligament of the femoral head (arrow) which extends from the femoral head (a) in the caudal elongation of the acetabular notch to the cranioventral surface of the body of the ischium (c).

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379 **Fig. 7.** Ventral views of a left canine hip joint. A. Dissected joint; B. Arthrologic
 380 specimen; C. Overview of the arthrologic specimen. Femoral head (a), acetabulum (b),
 381 transverse acetabular ligament (c), ligament of the femoral head (asterisk), accessory
 382 ligament of the femoral head (arrow).