Morpho-functional Evaluation of the Fibrous Elements of the Normal Femorotibial Articulation in Adult Dogs (*Canis familiaris*)

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Abstract

Objectives: The current study highlighted the basic anatomy of the ligamentous apparatus and the synovial membrane of the femorotibial articulation in healthy adult dogs. The study also aimed to give morphometric data about the length and width of the canine collateral femorotibial ligaments and to demonstrate whether or not there were sex differences in these dimensions.

Animals: Eight male and four female dogs were used in the study.

Procedures: Radiography and careful dissection were performed to document the gross morphology of the fibrous components of the femorotibial articulation.

With the use of SEM, the collateral femorotibial ligaments and the synovial membrane of the studied joint were also carried out.

Results: The study revealed the gross features of the fibrous elements of the femorotibial articulation in adult dogs. SEM also emphasized the morphologic characteristics of the collateral femorotibial ligaments and the synovial membrane of this joint.

Conclusions: Alterations in any structural element of the femorotibial articulation would contribute significantly to dysfunction of the entire stifle joint which is manifested by pain and troubles in the pelvic limb movement.

Therefore, understanding of the normal anatomy of this joint is essential for breeders, veterinarians and dog owners in order to properly diagnose and treat any joint injury. This will improve life quality of dogs and help them moving better. The data of the study might be used to obtain sufficient information about the specific features of the fibrous elements of the femorotibial articulation in normal adult dogs. Findings of this work might also evaluate the morpho-functional characteristics of this highly movable joint.

Keywords: Dog, Femorotibial articulation, Radiography, Morphometry, SEM

Introduction

The stifle (knee) joint in domestic mammals and humans is a complex joint both morphologically and functionally (De Rooster et al., 2006; Gupte et al., 2007 and Sabanci and Ocal, 2014). The complexity of the normal motion is directly related to the structure and functions of the anatomical components of the joint (Carpenter and Cooper, 2000).

The joint involved the femoropatellar, femorotibial, and proximal tibiofibular articulations in equines and canines (Skerritt and Mc Lelland,1984), in foxes (El Mahdy, 1992), and in goats (Fathi et al.,2016).

The femorosesamoidean articulation was considered as an additional component of the stifle joint in canines (Skerritt and Mc Lelland, 1984).

The bony architecture of the femur and tibia, the ligaments, the articular capsule, and the muscles crossing the joint stabilize the stifle joint, limit its normal range of mobility, and serve to distribute the biomechanical load on the joint (Goldblatt and Richmond, 2003 and Danila,2014). Osteoarthritis commonly occurs both in humans and animals is considered a serious disease which may affect the different structural components of the knee joint and can lead to lameness, pain, and dysfunction of the joint. (Carpenter and Cooper, 2000, Budras et al., 2001, Danila,2014 and Fellows et al., 2016).

Also, the femorotibial articulation in dogs is most commonly used in radiographic studies (Mauragis and Berry, 2012 and Hifny et al., 2017).

Anatomical deviations in any of the joint structures undoubtedly will lead to joint diseases. Knowledge of the normal anatomy of the fibrous elements of the femorotibial articulation allows selection of the best treatment for joint affections to restore the normal motion and to minimize further degeneration and dysfunction of the joint (Danila,2014).

Therefore, the goal of this work was to reveal and characterize the normal structural organization of the femorotibial articulation both grossly and by X-ray in adult dogs, as representatives of the family "Canidae" .

The work also aimed to shed light on the scanning electron microscopic description of the collateral ligaments and synovial capsule of the joint to provide essential knowledge for students and anatomists and to help veterinary surgeons and clinicians in the proper diagnosis and treatment of the joint injuries, especially chronic pain and limited mobility associated with osteoarthritis which necessitate removal of the damaged bone and replacement of the articular surfaces. The study might also be valuable for veterinary surgeons in order to repair the damaged collateral ligaments and use of allografts for surgical treatment of tear of the cruciate ligaments in adult dogs.

Moreover, some morphometric measurements were recorded in the current study, which might be taken as markers for evaluation of the normal growth and development of the dog's body, particularly the locomotor system and consequently the high performance of its tasks.

On the basis of these items, it was possible to establish the criteria of evaluation of the morpho-functional characteristics and the physiological status of this highly important joint in the body.

Results of the current study revealed the general construction and the specific morphologic organization of the femorotibial articulation which reflected the habitat, biomechanical characteristics of the movement behavior, and the character of the joint motion in dogs.

Materials and Methods

Twelve adult dogs of both sexes (8 males and 4 females) with their body weights ranged from 10 to 15 kg were used in the present study. The animals showed no evidence of any obvious bone or joint abnormalities. They were euthanized using an intravenous injection of thiopental sodium. The pelvic limbs of these animals were then separated after euthanasia.

All experimental animal techniques used in the present work were in accordance with the Faculty of Veterinary Medicine, Suez Canal University, Egypt.

1) Radiographic examination

Four fresh pelvic limbs were examined using digital radiology equipment. Caudo-cranial and medio-lateral radiographic images were taken to document the normal morphology of the osseous components of the dog's femorotibial articulation.

The exposure factors used were 66 KVP, 3 mAs, and a focal film distance (FFD) of 70 cm, with the joint placed directly on the cassette or detector.

2) Gross anatomic description

Gross morphology of the bones, ligaments, and capsule of the femorotibial articulation was described

3) Morphometric study

The length and width of the medial and lateral femorotibial ligaments in the dissected joints were measured. The length was measured as the distance between the most proximal and most distal points of bony attachments throughout the longitudinal axis of the ligament, while the width of the ligament was measured at the mid-distance between its points of bony attachment. The previous measurements were taken from all dissected right and left joints in both sexes using Vernier's caliber and the Image-J analysis system. The recorded measurements were calculated as means± standard deviation, and the statistical differences were determined using Statistical Package for Social Science (SPSS) software program version 16 and Excel Microsoft office program. Differences between male and female adult dogs were determined using independent sample T-test. The results were considered statistically significant at $P < 0.05$.

4) Scanning electron microscopic examination

Small pieces from the collateral femorotibial ligaments and the synovial membrane were taken from the remaining four joints.

The tissue specimens were preserved in 4% glutaraldehyde solution overnight at 4°C, then washed in 0.1M phosphate buffer (PH 7.2-7.4) for 4 hours followed by immersion in 1% osmic acid for 24 hours as a second fixation step. Thereafter, the specimens were put in ascending grades of ethyl alcohol solutions for 15 minutes in each for dehydration. Then, they were put in t-butyl alcohol for dryness, and finally frozen at -20°c. The specimens were then mounted on aluminum stubs with double-sided adhesive tape and coated with gold. The previous preparation procedures were done as provided by (Fujioka et al., 2013).

The tissue specimens were examined using a QUANTA FEG 250 scanning electron microscope.

5) Nomenclature

The terminology used in this study was adopted according to Nomina Anatomica Veterinaria (N.A.V., 2017) and Nomina Histologica Veterinaria (N.H.V., 2017) as needed.

Results

A) Gross anatomic characteristics

The femorotibial articulation (Articulatio femorotibialis) in dogs was a complex bicondylar synovial joint. This articulation, in addition to other components of the stifle joint contained together within a strong common articular capsule.

The femorotibial articulation was constructed between the spheroidal, strongly convex femoral condyles and the corresponding nearly flat tibial condyles as well as the intervening C-shaped fibrocartilaginous menisci.

A wide and deep intercondyloid fossa (Fossa intercondylaris femoris) was located between the medial and lateral femoral condyles.

The femoral epicondyles were seen above and slightly cranial to the corresponding femoral condyles in the form of two small rough prominences and served for the proximal attachment of the medial and lateral collateral femorotibial ligaments.

A short intercondyloid spine or eminence (Eminentia intercondylaris) was located between the two tibial condyles. The latter condyles were caudally interrupted by the popliteal notch through which the tendon of origin of the M. popliteus passed (Figs. 1, 2, 3, 4).

I- Ligaments of the femoro-tibial articulation

(a) Ligg. collaterale tibiale (mediale) et fibulare (laterale)

The medial and lateral collateral ligaments were asymmetrical in length and width and attached the distal end of the femur to the proximal end of the tibia and fibula.

(1) Lig. collaterale laterale (fibulare) (Figs. 5, 9)

The lateral (fibular) collateral femorotibial ligament extended from the lateral epicondyle of the femur just above the attachment point of the popliteus muscle and terminated on the head of the fibula as well as the peripheral margin of the lateral tibial condyle.

(2) Lig. collaterale mediale (tibiale) (Fig. 6)

The medial (tibial) collateral femorotibial ligament appeared as a fibrous longitudinal band that arose proximally from the medial epicondyle of the femur and terminated distally in the medial border of the tibia about 2 cm distal to the margin of the medial tibial condyle. The medial ligament was much longer, wider, and slightly thicker than the lateral one.

(b) Ligg. cruciata genus

The two cruciate ligaments were located between the femur and tibia within the femorotibial joint cavity. They crossed each other and covered by the synovial membrane of the articular capsule. Both ligaments were best seen from the cranial aspect of the joint after opening the fibrous capsule and during flexion of the joint, where they were surrounded by some fatty tissue.

The cruciate ligaments nearly occupied the intercondyloid fossa of the femur proximally and the intercondyloid areas of the tibia distally.

(1) Lig. cruciatum craniale (Fig. 7)

The fascicles of the cranial cruciate ligament possessed a highly twisted appearance. They started from the cranial intercondyloid area of the tibial plateau as well as the medial intercondyloid tubercle of the tibial spine just behind the transverse meniscal ligament.

The cranial cruciate ligament was directed proximally towards the intercondyloid fossa of the femur and attached at the medial margin of the lateral femoral condyle.

(2) Lig. cruciatum caudale (Figs. 7, 8)

The caudal cruciate ligament appeared nearly similar in length and relatively thicker compared to the cranial cruciate ligament. However, its fascicles were less twisted than those of the cranial cruciate ligament.

It attached proximally at the craniomedial wall of the femoral intercondyloid fossa and with the inner surface of the medial femoral condyle.

The ligament was fixed distally in the caudal intercondyloid area of the tibial plateau, the popliteal notch, and the caudal edge of the medial tibial condyle.

II- Articular Capsule

The articular capsule (Capsula articularis) is one of the principal structures of the femorotibial articulation, as a synovial joint. It holds the articulating bones together and is composed of an outer fibrous layer and an inner synovial one.

1. Stratum fibrosum or Membrana fibrosa

The fibrous layer of the articular capsule (Fig.9) appeared characteristically extensive, thick, and strong. Therefore, it played a significant role in protection and stability of the joint, as well as allowed its free movement.

It consisted of dense, inelastic white fibrous connective tissue membrane that reinforced on both sides by the collateral femorotibial ligaments, and was much thinner on the caudal aspect of the joint.

It was firmly attached with the peripheral edge of the medial meniscus and the medial collateral ligament, while loosely connected with the peripheral edge of the lateral meniscus since the tendon of origin of the popliteus muscle was interposed between them.

2. Stratum synoviale or Membrana synovialis

By the naked eye, the synovial membrane appeared very thin, glistening and transparent. It enclosed the articular cavity entirely, but was absent on the articular cartilage. It lined the inner aspect of the fibrous layer by which it is supported and covered the cruciate ligaments as well as the menisci.

B) Morphometric findings (Tables 1, 2, 3 and Figs. 10, 11)

The length of both right and left medial femorotibial ligaments in an adult dog was 3.16 ± 0.07 cm, while that of the right and left lateral collateral ligaments measured 2.92 ± 0.05 cm. The width of the right and left medial collateral ligaments was 0.47 ± 0.04 cm, whereas the width of both right and left lateral collateral ligaments measured 0.42 ± 0.02 cm. Therefore, the medial femorotibial ligament was significantly ($P < 0.05$) longer and wider compared to the lateral femorotibial ligament of the same joint.

However, the length and width of both medial and lateral collateral ligaments in the right and left joints of the same animal of both sexes were nearly identical.

Statistical analysis of the current morphometric data established a correlation between the ligamentous length and width related to the sex of the animal and revealed that male dogs generally presented significantly larger dimensions compared to female dogs ($P < 0.05$). Thus, the right and left medial femorotibial ligaments in male dogs measured 3.36 ± 0.42 cm long and 0.51± 0.07 cm wide, whereas these dimensions for the right and left lateral collateral ligaments were 3.12 ± 0.36 cm and 0.45± 0.08 cm in length and width, respectively.

On the other hand, such dimensions in female dogs were 2.69 ± 0.14 cm and 2.47 ± 0.20 cm in length for the medial and lateral collateral ligaments, respectively. While the width dimensions in females were 0.40 ± 0.06 cm and

0.37 ± 0.06cm for the medial and lateral collateral ligaments, respectively.
There were no significant differences between the various ligamentous dimensions that were obtained with the use of either Vernier's caliber or the Image-J system.

C) Scanning electron microscopic findings

●The collateral femorotibial ligaments (Ligg. femorotibialis collaterale)

Scanning electron micrographs revealed highly organized and condensed collagen fibers and fascicles that oriented along the longitudinal axis of both collateral femorotibial ligaments in a wavy parallel pattern. These collagen fibers and fascicles were tightly joined together by multiple cross communications that occurred via meshwork of numerous fine collagen fibrils. The collagen fascicles varied in their widths and separated from each other by narrow groove- like spaces. It was also observed that some collagen fibers within a fascicle were less wavy, and other fibers were straight in their course. Higher magnification scanning electron micrographs revealed that each individual collagen fiber consisted of numerous fine packed, thread-like collagen fibrils that were nearly equal in diameter and exhibited regular intervals between each other (Figs. 12, 13).

●The synovial membrane (Membrana synovialis)

High magnification scanning electron micrographs of the synovial membrane of the dog's femorotibial articulation revealed that its luminal surface was thrown into a very large number of synovial microvilli that projected into the articular cavity and exhibited variable forms and heights.
Two different forms of the synovial microvilli were recognized. Some of them appeared flattened, oval, or even round in shape.
The other type of the microvilli crossed each other to form a sort of meshwork on the luminal surface of the synovial membrane (Fig. 14).

Discussion

A) Gross anatomic characteristics

Results of the current study revealed the general conformation and the specific morphologic organization of the femorotibial articulation which reflected the habitat, biomechanical characteristics of the movement behavior, and the character of the joint motion in dogs.
The anatomic construction of the femorotibial articulation in dogs was similar to that described in horse (Dyce et al.,2010), donkeys and goats (Abumandour et al.,2019), canines (Dyce et al., 2010), cattle (Goldblatt and Richmond, 2003) as well as cattle and buffalo (El Hanbaly, 2011).
Our study in dogs described that both the medial and lateral femoral condyles were spheroidal and strongly convex. However, these condyles

presented variable shapes in canines (Samuelson,2007).

The deep and wide intercondyloid fossa that present caudally between the medial and lateral femoral condyles in dogs was also mentioned in cattle and buffalo (El Bably and Noor, 2017).

The medial and lateral tibial condyles in dogs were dissimilar in shape where the medial condyle was oval, whereas the lateral condyle was nearly circular. This finding agreed somewhat with (Fathi et al.,2016) also in dogs, who stated that the medial tibial condyle was nearly semicircular or oval and the lateral condyle was saddle-shaped or circular. However, both tibial condyles were described as saddle-shaped in horses (Dyce et al., 2010), cattle and buffalo (El Hanbaly, 2011).

The femoral and tibial condyles in dogs and other domestic animals as well as in humans did not conform to each other. Therefore, the two fibrocartilaginous menisci were interposed to provide congruence and improve the poor fit between them (Goldblatt and Richmond, 2003, Dyce et al., 2010 and Fathi et al.,2016).

Regarding the medial and lateral collateral ligaments as well as the cruciate ligaments of the femorotibial articulation in dogs, they were nearly similar in their orientation and bony attachment as in other animals and humans. The close attachment of the medial meniscus to the joint capsule, and lack of such attachment for the lateral meniscus was also noticed by (Abumandour et al.,2019 and Abumandour et al.,2020) in donkeys.

The cranial cruciate ligament in the cow, sheep and pig stifle joint was separated by the cranial attachment of the lateral meniscus into cranio-medial and caudo-lateral bundles. However, it was not divided in humans and goats (Proffen et al.,2012), confirming the current results in dogs.

Moreover, the femoral attachment of the cranial cruciate ligament at the caudo-medial edge of the lateral femoral condyle in dogs resembled that observed in cows, sheep, goats, pigs, and rabbits (Proffen et al.,2012).

The present work reported that the fascicles of the cranial cruciate ligament were more twisted and thinner compared to the caudal cruciate ligament, resembling the observations for cattle (Hifny et al.,2017).

The cranial cruciate ligament seemed to be the most vulnerable ligament of the canine stifle joint which might cause the high incidence of the cranial cruciate ligament damage (Sabanci and ocal,2014).

B) Morphometric characteristics

Regarding the dimensions of the collateral ligaments, our results concluded that the lateral femorotibial ligaments in both sexes were significantly shorter and narrower compared to the analogous medial ligaments. This might be due to the difference between the angles of the medial and lateral tibial condyles and their axial relationship with the overlying respective femoral condyles. It also might be due to the attachment of the lateral femorotibial ligament at the margin of the lateral tibial condyle as well as at the fibular head, which articulated with the lateral tibial condyle at its caudo-lateral angle. In this connection, the medial femorotibial ligament was reported to be more than 4 cm long in medium-sized dogs (Ocal et al.,2012 and Sabanci and ocal, 2014).

Similar relative values of the length and width of the collateral femorotibial ligaments were recorded in cattle, where the lateral collateral ligament measured 9.7 cm long and 1.40 cm wide, while the medial collateral ligament was longer (~ 10.7 cm) and wider (~ 1.48 cm) (Hifny et al.,2017**).**

C) Scanning electron microscopic characteristics

The ligamentous apparatus constituted one of the basic components of the synovial joint necessary for its structural and functional integrity (Dyce et al.,2010). The synovial membrane shared in formation of the synovial medium of any synovial joint (Eurell and Frappier, 2006 and Dyce et al.,2010).

●The collateral femorotibial ligaments:

High magnification scanning electron micrographs revealed that most of the collagen bundles of the collateral femorotibial ligaments in dogs were highly undulated and separated from each other by deep grooves and depressions. The wavy orientation of the collagen fibers of the ligaments allows their stretching during tensile forces (De Rooster et al., 2006).

In agreement with (Eurell and Frappier, 2006 and Ocal et al.,2012), the multiple fibrillar communications observed between the collagen bundles undoubtedly increased the strength of the fibrous building of the ligament to maintain its function**.**

In accordance with (De Rooster et al., 2006)., each collagen fiber consisted of numerous thread-like collagen fibrils, which were equal in diameter.

●The synovial membrane:

Concerning the synovial membrane, it was described as a highly vascularized layer of serous connective tissue which secretes the synovial fluid responsible for the nutrient exchange between blood and the joint (Danila et al.,2014).

The two types of the synovial microvilli described in our study according to their form were projected from the synovial villi of the synovial membrane of the canine femorotibial articulation. This might indicate the good and healthy status of the joint during motion. However, observations of previous authors in other different synovial joints revealed two types of synoviocytes. The first type of cells was spherical, macrophage-like cells, while the second type of synoviocytes was fibroblast-like cells that were consistently

distributed over the synovial villi (Iwanaga et al.,2000 and Alsafy et al.,2015).
A third type of cells (intermediate lining cells) located on the surface of the intima layer and these cells were smaller in size than the macrophage-like cells and had more intensely stained nuclei (Alvez et al.,2014).

Conclusions

1- The current study revealed that the construction of the femorotibial articulation in dogs was similar to that in other domestic animals.
2- The general conformation of the femorotibial articulation reflected the habitat, biomechanical characteristics of the movement behavior, and the character of the joint motion in dogs.
3- The lateral femorotibial ligaments in all dissected joints in both sexes were significantly shorter and narrower compared to the analogous medial ligaments. This might be due to the difference between the angles of the medial and lateral tibial condyles and their axial relationship with the overlying respective femoral condyles.
5- Two types of microvilli according to their form projected from the synovial membrane of the canine femorotibial articulation, which undoubtedly provide healthier joint during movement.

Conflict of interest:

The authors declare that they have no conflicts of interest.

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Table (1) showing the dimensions /cm of the length (L) and width (W) of the medial and lateral femorotibial ligaments in male (M) and female (F) adult dogs using "Vernier's caliper"

No.	sex	Right femorotibial articulation				Left femorotibial articulation			
		Medial collateral ligament		Lateral collateral ligament		Medial collateral ligament		Lateral collateral ligament	
		L	W	L	W	L	W	L	W
1	M	2.87	0.49	2.69	0.42	2.86	0.48	2.68	0.40
2	M	3.84	0.48	3.71	0.31	3.82	0.35	3.72	0.30
3	M	3.88	0.44	3.39	0.42	3.86	0.44	3.38	0.41
4	M	3.65	0.62	3.33	0.57	3.64	0.64	3.32	0.58
5	M	3.26	0.56	2.98	0.49	3.26	0.56	2.98	0.47
6	M	3.14	0.48	2.91	0.43	3.13	0.48	2.90	0.44
7	M	2.93	0.58	2.84	0.52	2.92	0.56	2.86	0.51
8	F	2.85	0.44	2.70	0.41	2.87	0.43	2.72	0.40
9	F	2.58	0.44	2.32	0.40	2.59	0.45	2.33	0.40
10	F	2.66	0.33	2.39	0.30	2.65	0.32	2.40	0.31
Mean ± SD		3.16 ±0.07	0.47 ±0.04	2.92 ±0.05	0.42 ±0.02	3.16 ±0.07	0.47 ±0.04	2.92 ± 0.06	0.41 ± 0.02

Table (2) showing the dimensions /cm of the length (L) and width (W) of the medial and lateral femorotibial ligaments in male (M) and female (F) adult dogs using the "Image-J system "

No.	Sex	Right femorotibial articulation				Left femorotibial articulation			
		Medial collateral ligament		Lateral collateral ligament		Medial collateral ligament		Lateral collateral ligament	
		L	**W**	**L**	**W**	**L**	**W**	**L**	**W**
1	M	2.86	0.47	2.70	0.41	2.84	0.49	2.66	0.38
2	M	3.82	0.49	3.73	0.30	3.81	0.32	3.73	0.29
3	M	3.87	0.43	3.38	0.41	3.85	0.45	3.40	0.40
4	M	3.65	0.60	3.36	0.55	3.62	0.62	3.30	0.58
5	M	3.24	0.54	2.96	0.50	3.26	0.56	2.94	0.48
6	M	3.14	0.48	2.92	0.42	3.11	0.46	2.92	0.42
7	M	2.91	0.57	2.86	0.50	2.92	0.58	2.86	0.51
8	F	2.86	0.44	2.72	0.40	2.89	0.44	2.75	0.42
9	F	2.55	0.42	2.32	0.41	2.61	0.44	2.30	0.40
10	F	2.66	0.33	2.41	0.32	2.66	0.34	2.39	0.30
Mean± SD		3.15 ±0.06	0.47 ± 0.04	2.93 ± 0.05	0.42 ±0.02	3.15 ±0.06	0.47 ±0.04	2.92 ± 0.05	0.41 ± 0.02

Table (3) showing the dimensions /cm of the length and width of the medial and lateral femorotibial ligaments in male and female adult dogs.

Left medial collateral ligament

	Male	Female
Length (cm)	3.35 ± 0.42	2.70 ± 0.15
Width (cm)	0.50 ± 0.09	0.40 ± 0.07

Left lateral collateral ligament

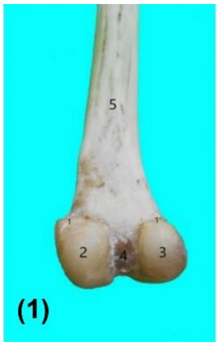
	Male	Female
Length (cm)	3.12 ± 0.36	2.48 ± 0.21
Width (cm)	0.44 ± 0.09	0.37 ± 0.05

Right medial collateral ligament

	Male	Female
Length (cm)	3.36 ± 0.42	2.69 ± 0.14
Width (cm)	0.52 ± 0.07	0.40 ± 0.06

Right lateral collateral ligament

	Male	Female
Length (cm)	3.12 ± 0.36	2.47 ± 0.20
Width (cm)	0.45 ± 0.08	0.37 ± 0.06



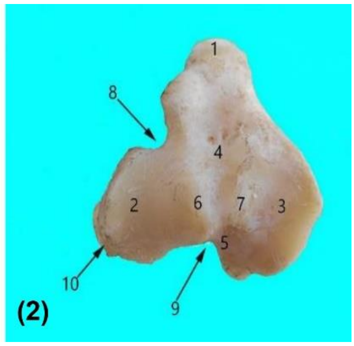


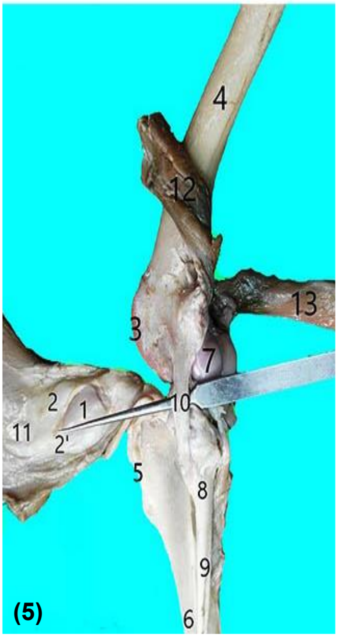
Fig. (1): A photograph of the distal extremity of dog femur (caudal aspect) showing:
1,1` Facies articularis sesamoidea lateralis et medialis, 2 Condylus lateralis femoris, 3 Condylus nedialis femoris, 4 Fossa intercondylaris femoris, 5 Corpus ossis femoris

Fig. (2): A photograph of the dog tibial plateau showing:
1 Tuberositas tibiae, 2 Condylus lateralis, 3 Condylus medialis, 4 Area intercondylaris cranialis, 5 Area intercondylaris caudalis, 6 Tuberculum intercondylare laterale, 7 Tuberculum intercondylare mediale, 8 Sulcus extensorius, 9 Incisura poplitea, 10 Facies articularis os sesamoideum m. poplitei

Fig. (3): A medio-lateral radiographic image of the dog stifle joint showing:
1 Corpus ossis femoris, 2 Patella, 3 Trochlea ossis femoris (medial ridge), 4 Epicondylus medialis femoris, 5 Os sesamoideum m.gastrocnemii medialis, 6 Os sesamoideum m.gastrocnemii lateralis, 7 Condylus medialis femoris tuberositas tibiae, 8 Crista tibiae , 9 Condylus medialis tibiae, 10 Os sesamoideum m. poplitei, 11 Caput fibulae, 12 Corpus fibulae, 13 Corpus tibiae

Fig. (4): A caudo-cranial radiographic image of the dog stifle joint showing:
1 Corpus ossis femoris, 2 Condylus medialis femoris, 3 Condylus lateralis femoris, 4 Condylus medialis tibiae, 5 Condylus lateralis tibiae, 6 Incisura poplitea, 7 Fossa intercondylaris femoris, 8 Caput fibulae, 9 Corpus fibulae, 10 Corpus tibiae, 11 Eminentia intercondylaris tibiae.

† Black arrows indicate the Ossa sesamoidea m. gastrocnemii
† Red arrow indicates the Os sesamoideum m. poplitei



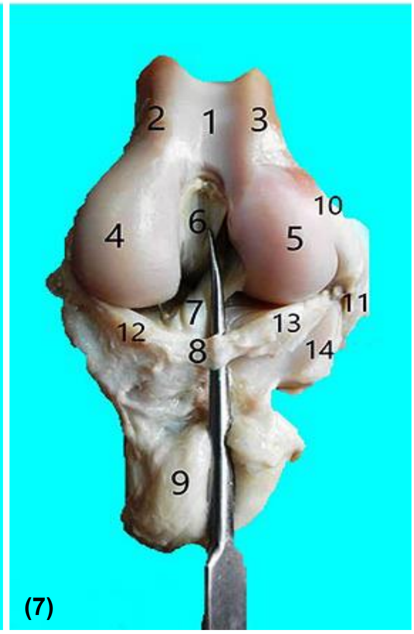
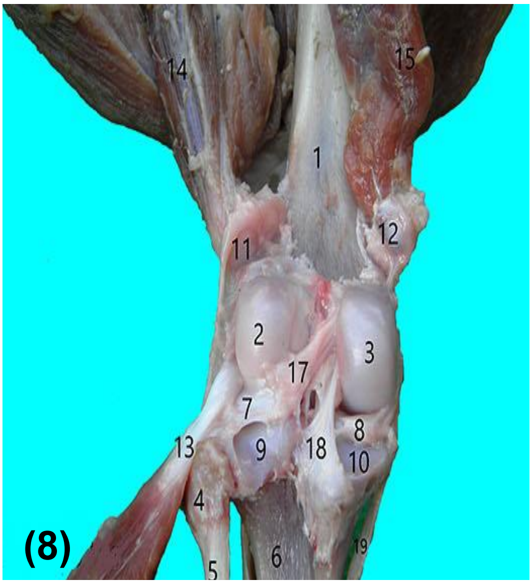


Fig. (5): A photograph of the dog femorotibial articulation (lateral aspect):
1 Facies articularis patellae, 2 Fibrocartilaginous parapatellaris medilais 2`Fibrocartilaginous parapatellaris lateralis ,3 Trochlea ossis femoris (lateral ridge), 4 Corpus ossis femoris, 5 Tuberositas tibiae, 6 Corpus tibiae, 7 Condylus lateralis femoris, 8 Caput fibulae, 9 Corpus fibulae, 10 Lig. collaterale laterale (fibulare),11 M. quadriceps femoris (insertion tendon), 12 M. gastrocnemius (caput laterale),13 M. gastrocnemius (caput mediale)

Fig. (6): A photograph of the dog femorotibial articulation (medial aspect):
1 Trochlea ossis femoris (medial ridge),2 Corpus ossis femoris, 3 Tuberositas tibiae, 4 Corpus tibiae, 5 Lig. collaterale mediale (tibiale)

Fig. (7): A photograph of the distal extremity of femur (the patella is reflected downward):
1 Facies patellae ossis femoris, 2 Trochlea ossis femoris (medial ridge), 3 Trochlea ossis femoris (lateral ridge), 4 Condylus medilais femoris, 5 Condylus lateralis femoris, 6 Lig. cruciatum caudale, 7 Lig. cruciatum craniale, 8 Lig. transversum genus, 9 Patella, 10 Epicondylus lateralis femoris, 11 Lig. collaterale laterale, 12 Meniscus medialis, 13 Meniscus lateralis,14 Condylus lateralis tibiae



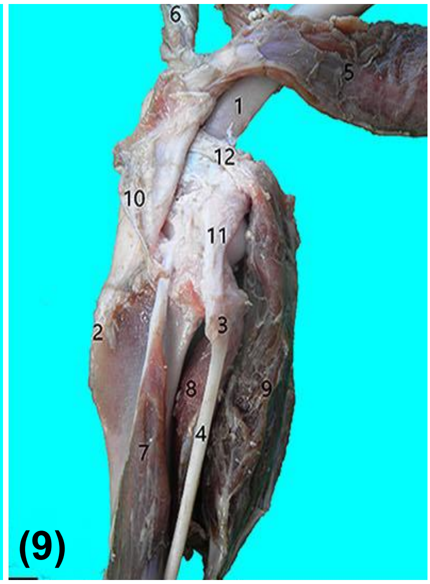
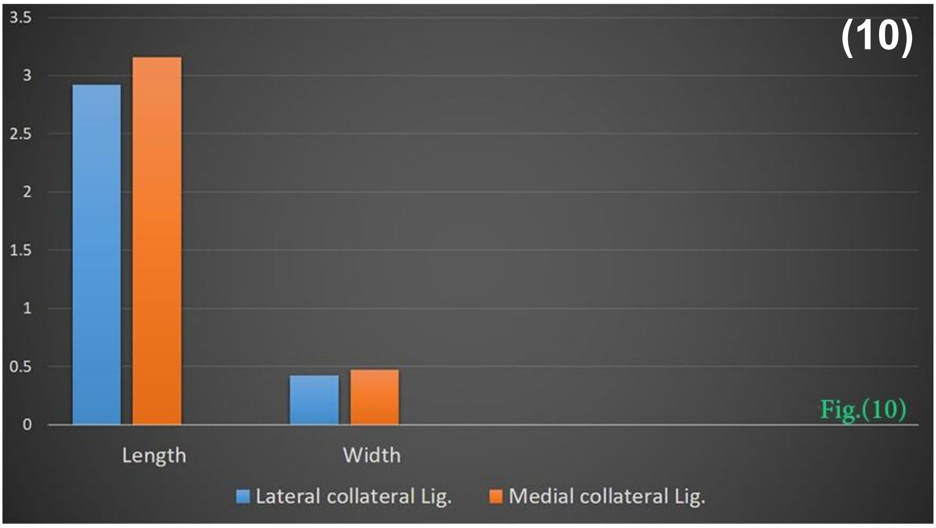


Fig. (8): A photograph of the dog femorotibial articulation (caudal aspect):
11 Corpus ossis femoris, 2 Condylus lateralis femoris, 3 Condylus medialis femoris, 4 Caput fibulae, 5 Corpus fibulae,6 Corpus tibiae, 7 Meniscus lateralis, 8 Meniscus medialis, 9 Condylus lateralis tibiae, 10 Condylus medialis tibiae, 11 Os sesamoideum m. gastrocnemii lateralis, 12 Os sesamoideum m. gastrocnemii medialis, 13 Os sesamoideum m. poplitei, 14 M. gastrocnemius (caput laterale), 15 M. gastrocnemius (caput mediale), 16 M. Popliteus (displaced), 17 Lig. meniscofemorale ad meniscus lateralis, 18 Lig. cruciatum caudale, 19 Lig. collaterale mediale (tibiale)

Fig. (9): A photograph of the femorotibial articulation (lateral aspect) showing:
1 Corpus ossis femoris, 2 Tuberositas tibiae, 3 Caput fibulae, 4 Corpus fibulae, 5 M. biceps femoris, 7 M. rectus femoris, 8 M. extensor digitorum longus, 9 M. gastrocnemius (caput mediale), 10 M. gastrocnemius (caput laterale), 11 Capsula articularis (reflected), 12 Lig. collaterale laterale(fibulare), 13 Lig. fabellopatellare laterale



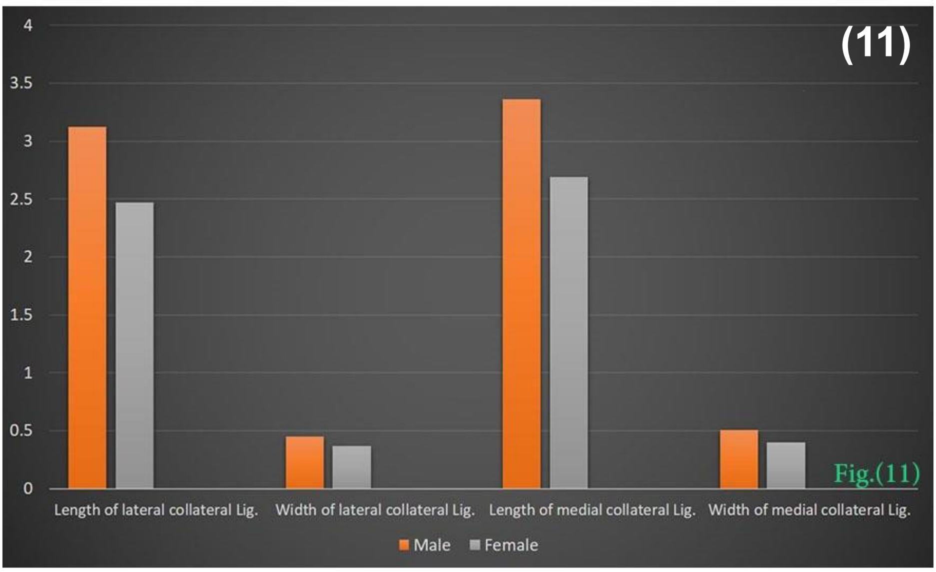
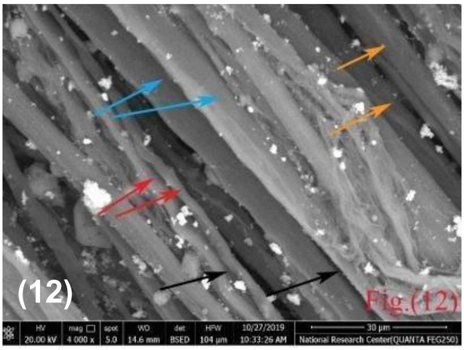
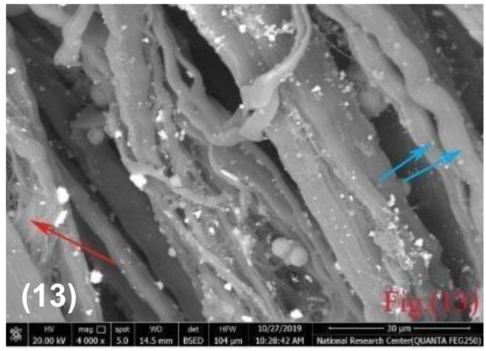


Fig. (10): A histogram showing the length and width /cm of both medial and lateral collateral femorotibial ligaments in an adult dog.

Fig. (11): A histogram showing the relationship between the length and width /cmof both medial and lateral collateral femorotibial ligaments and the animal sex.





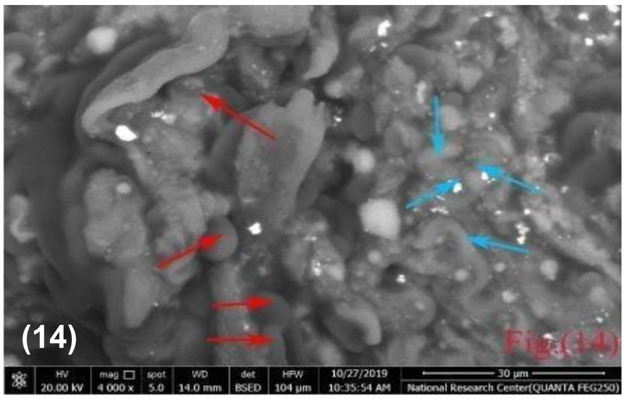


Fig. (12): A high magnification scanning electron micrograph of the collateral femorotibial ligament of an adult dog showing the parallel and densely oriented collagen bundles and the narrow groove-like spaces among them (X 4,000)

- Strongly wavy collagen bundles (red arrows)
- Less wavy collagen bundles (blue arrows)
- Straight collagen bundles (yellow arrows)
- Groove-like spaces among the collagen bundles (black arrows)

Fig. (13): A high magnification scanning electron micrograph of the collateral femorotibial ligament of an adult dog showing: (X 4,000)

- Highly wavy collagen bundles (blue arrows)
- Meshes of collagen fibrils (red arrow) between the collagen bundles

Fig. (14): A high magnification scanning electron micrograph showing microvilli of different forms and heights that carried on the luminal surface of the synovial membrane. (X 4,000)

- Microvilli forming a meshwork on the luminal surface (blue arrows)
- Oval, flat, or round microvilli (red arrows)