DOI : 10.5958/2277-8934.2017.00015.7 *Vol 24 No 1, p 99-106*

MORPHOLOGICAL AND MORPHOMETRIC STUDY ON STIFLE JOINT OF DROMEDARY CAMEL (*Camelus dromedarius*)

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ABSTRACT

Morphological and morphometric study was conducted on 10 freshly collected stifle joints from cadaver of adult dromedary camels (*Camelus dromedarius*) of local breed. In morphological study all the important anatomical structures were identified. The medial patellar ligament could not be evidenced but a medial femoropatellar ligament running between the medial epicondyle of femur and patella was found. Another strap like ligament like structure originating from medial femoral fascia and inserted on the tibial tuberosity was evidenced and it was supposed to support the patella in its normal position. The medial collateral ligament was present but its lateral counterpart could not be evidenced. The medial intercondylar tubercle of tibia was found to be somewhat elevated and larger than the lateral one. Morphometric data (length, width and thickness) of the important ligaments and anatomical structures (articular surfaces) were measured. The orientation of the medial femoro patellar ligament was at an angle of 113.8° ± 1.93° with the middle patellar ligament. There was an angle of 82.7° ± 1.77° between the meniscofemoral ligament and the ligament connecting the menisci caudally. Descriptive statistics were given as Mean ± SD (standard deviation) along with coefficient of variation to show variability of a particular dimension.

Key words: Camel, morphology, morphometry, stifle joint

Camel is an even toed ungulate, pseudo ruminant mammal and an important animal component of the fragile desert eco-system. Camel is mainly used as a drought animal in India and any affection of the stifle joint can affect the working efficiency of the animal. The incidence of hind limb lameness (54.68%) is more as compared to forelimb lameness (45.31%) in camel. Moreover the upward fixation of patella is the 3rd most common (10.71%) cause of hind limb lameness (Gahlot, 2007). The most commonly described stifle joint affections are gonitis and upward fixation of patella (Vaughan, 1965 and Wheat, 1972). The latter is the most prevalent stifle affection in camel (Krishnamurthy *et al*, 1992). Other affections of stifle joint include the rupture of cruciate ligament (Purohit *et al*, 1988a; Pearce and Hurtig, 1999 and Marriott *et al*, 1999), fibrotic myopathy of thigh muscles affecting the movement of the stifle joint (Purohit *et al,* 1988b), arthritis of stifle joint i.e. gonitis (Gahlot, 2000), poisoning of *Capparis tomentosa,* a medicinal plant leading to stiffness of stifle joint (Schwartz and Dioli, 1992). This can impose an economical set back to poor farmers making camel stifle joint an important anatomical structure for research.

Gross anatomical dissection studies on stifle joint have been done previously in camel (Siddiqui and Telfah, 2010), llama (Semevolos, 2005), cattle (Uddin *et al*, 2009), cattle and buffalo (Hifney *et al*, 2013) and ovine (Vandeweerd *et al,* 2012) with good results and excellent contribution in anatomical studies. The present study was thus planned for morphological and morphometric analysis of stifle joint of camel.

Materials and Methods

The study was carried out on 10 freshly collected stifle joints from cadaver of adult dromedary camels (*Camelus dromedarius*) of local breed. The studied specimens showed no evidence of marked bony abnormalities or degenerative disease. The study was done after carefully dissecting the skin and fascia covering the joint and nearby anatomical structures.

Morphological study

The morphological features of the stifle joint were studied as:

1) Femorotibial Articulation:

a) Ligaments

b) Articular surfaces and associated bones

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2) Femoropatellar Articulation:

a) Ligaments

b) Articular surfaces and associated bones

3) Menisci

Morphometric study

Morphometric data (length, width and thickness) of the important ligaments and anatomical structures (articular surfaces) were measured by Vernier caliper. These data were represented as Mean ± SD (standard deviation) in Table 1. The coefficient of variation was also calculated to show variability of a particular dimension. The statistical analysis was carried out with Microsoft® Excel 2007 program. The nomenclature used in the present work was adapted to the Nomina Anatomica Veterinaria (2005) as well as the available literature.

Results

I. Morphological Study

A. Femoro-tibial articulation:

This articulation was condylar type where femoral and tibial condyles articulate. Important anatomical structures evidenced on morphological study of this articulation were:

(i) Ligaments

Collateral Ligaments:

The **Lateral Collateral Ligament** was found absent (Fig 3).

The **Medial Collateral Ligament** runs from an eminence on the medial epicondyle of the femur to the medial proximal aspect of the tibia (Fig 5).

Cruciate Ligaments:

There was evidence of 2 well developed cruciate ligaments:

The **Cranial Cruciate Ligament** (Fig 1) had origin from the cranial intercondylar area of tibia and inserted on the lateral intercondylar surface of femur.

The **Caudal Cruciate Ligament** (Fig 7) had origin from caudal intercondylar area of tibia and had 2 insertions i.e. one on the cranial surface of medial intercondylar area of femur the main insertion and another more cylindrical attached lateral to it.

(ii) Articular Surfaces and Associated Bones:

Distal Femur

Condyles of femur were found to be placed at a slight angle directed caudolaterally (Fig 1). The intercondylar fossa had 3 depressions for the attachment of ligaments. The medial epicondyle (Fig 6) had a prominence for ligament attachment while the lateral epicondyle was relatively smooth.

Proximal Tibia

The tibia was triangular proximally and tapered down towards the cylindrical distal end. The 2 articular surfaces of tibia were lateral and medial tibial condyles. The lateral condyle was roughly trapezoid in shape whose narrow border end towards the lateral intercondylar tubercle. The medial condyle was larger and more rounded in shape and continued along the surface of medial intercondylar tubercle (Fig 8). The medial intercondylar tubercle was slightly higher in position than its lateral counterpart (Fig 8). There were depressions in the caudal intercondylar area for the attachment of ligaments. There was a depression between the lateral tibial condyle and the anterior tibial tuberosity. The tibial tuberosity was very well developed, irregular and directed craniodorsally (Fig 8). It was indented along its proximal surface to form a short sulcus. There was a shallow transverse depression distal to the latter.

B. Femoro-Patellar Articulation:

(i) Ligaments

This articulation was a sellar joint between the femoral trochlea and the patella. Various important anatomical structures evidenced on morphological study of this articulation were:

Middle Patellar Ligament appeared to be the only well developed ligament of patella which represents the insertion of quadriceps femoris muscle. It had origin from the craniodistal aspect of the patella and run distally as a strong wide fibrous band and inserted into the tibial tuberosity. A thick layer of adipose tissue cushion it from the joint capsule (Fig 4).

Medial Femoropatellar Ligament consists of a thin strap like ligamentous structure extended between the medial epicondyle of femur and the medial aspect of patella somewhat at mid. In addition to this or for better reinforcement of the joint there was a ligamentous band originating from the muscle fascia of the medial aspect. This band partly attaches to the medial femoral epicondyle and run in a craniodistal direction ending in the tibial tuberosity (Fig 4).

Lateral Patellar Retinaculum consists of a lateral femoropatellar ligament running between the lateral femoral epicondyle and the lateral aspect of patella at nearly distal end. It appeared to be fused

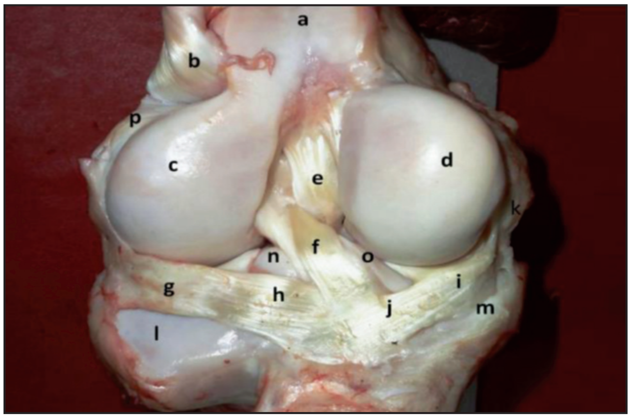

Fig 1. Gross anatomy of right stifle joint cranial view (joint capsule and patella removed).
(a) Trochlea, (b) Origin of muscle extensor digitorum longus and peronius tertius, (c) Lateral condyle of femur, (d) Medial condyle of femur, (e) Caudal cruciate ligament, (f) Cranial cruciate ligament, (g) Lateral meniscus, (h) Cranial attachment of lateral meniscus,(i) Medial meniscus, (j) Cranial attachment of medial meniscus, (k) Medial collateral ligament, (l) Lateral condyle of tibia, (m) Medial condyle of tibia, (n) Lateral intercondylar tubercle, (o) Medial intercondylar tubercle, (p) Popliteus muscle (origin).

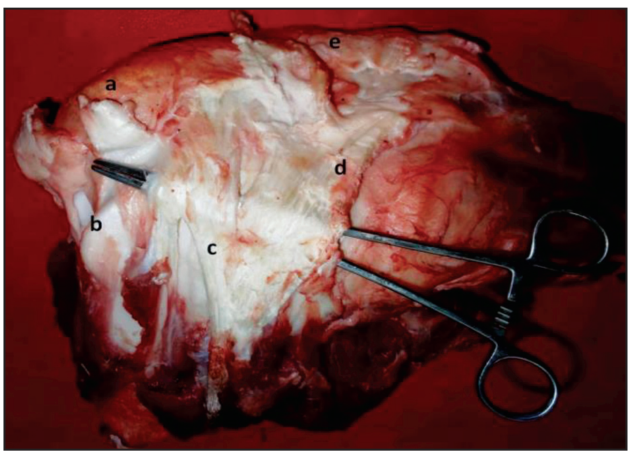

Fig 2. Gross anatomy of right stifle joint lateral view.
(a) Patella, (b) Lateral trochlear ridge, (c) Lateral femoropatellar ligament, (d) Insertion of Muscle gluteobiceps on patella and tibial tuberosity, (e) Middle Patellar Ligament.

with the middle patellar ligament at this level and also associated with the tendinous insertion of muscle gluteobiceps at patella and tibial tuberosity (Fig 2).

(ii) Articular Surfaces and Associated Bones:

a. Femoral Trochlea

The femoral trochlea consists of a gliding groove and trochlear ridges i.e. medial and lateral. The trochlea appeared to be directed distally and medially. The trochlear goove was smooth and congruent for articulation with patella. The lateral

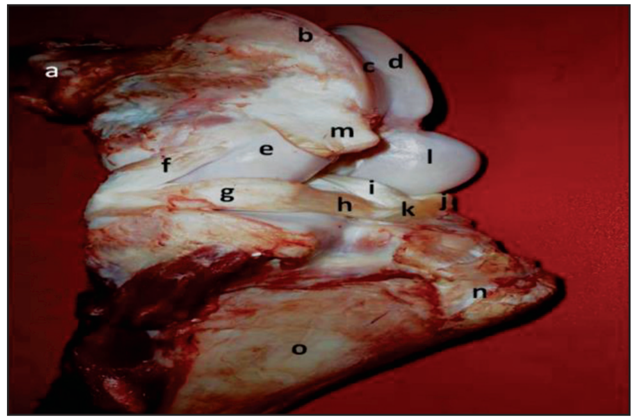

Fig 3. Gross anatomy of right stifle joint lateral view (joint capsule and patella removed).
(a) Femur, (b) Lateral trochlear ridge, (c) Femoral trochlea groove, (d) Medial trochlear ridge, (e) Lateral condyle of femur, (f) Popliteus muscle (origin), (g) Lateral meniscus, (h) Cranial attachment of lateral meniscus, (i) Cranial cruciate ligament, (j) Medial meniscus, (k) Cranial attachment of medial meniscus, (l) Medial condyle of femur, (m) Origin of muscle extensor digitorum longus and peronius tertius, (n) Tibial tuberosity, (o) Tibia.

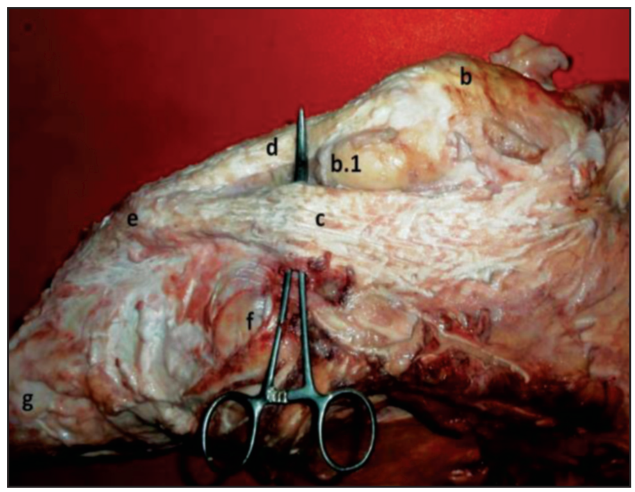

Fig 4. Gross anatomy of right stifle joint medial view.
(a) Femur, (b) Patella, (b.1) Apex of patella, (c) Ligamentous band from the medial femoral fascia, (d) Middle patellar ligament, (e) Tibial tuberosity, (f) Medial condyle of tibia, (g) Tibia.

trochlear ridge was longer and prominent than the medial counterpart (Fig 3).

b. Patella

Patella was elongated bone and had a base and an apex (Fig 5). The base was blunt directed proximally and the apex was pointed directed distally. The greater curvature of the bone was convex and rough for ligaments insertion. The lesser curvature was smooth and articulate with the femoral trochlea.

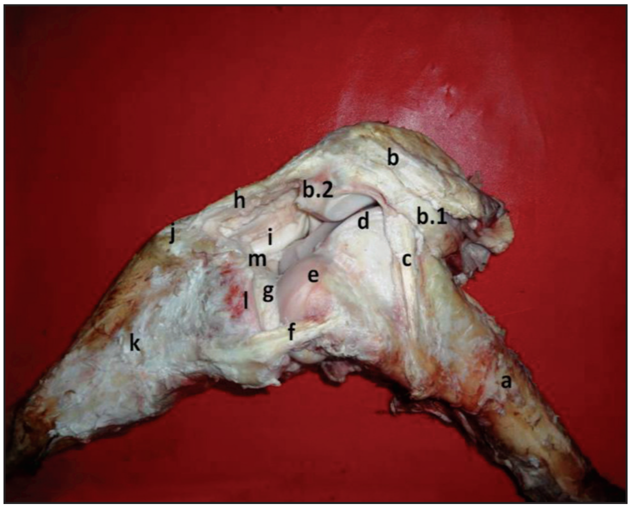

Fig 5. Gross anatomy of right stifle joint medial view I (joint capsule removed).
(a) Femur, (b) Patella, (b.1) Base of patella, (b.2) Apex of patella, (c) Medial femoro-patellar ligament, (d) Femoral trochlea, (e) Medial femoral condyle, (f) Medial collateral ligament, (g) Medial meniscus, (h) Middle patellar ligament, (i) Common tendon of origin of muscle extensor digitorum longus and peronius tertius, (j) Tibial tuberosity, (k) Tibia, (l) Medial tibial condyle, (m) Cranial attachment of medial meniscus.

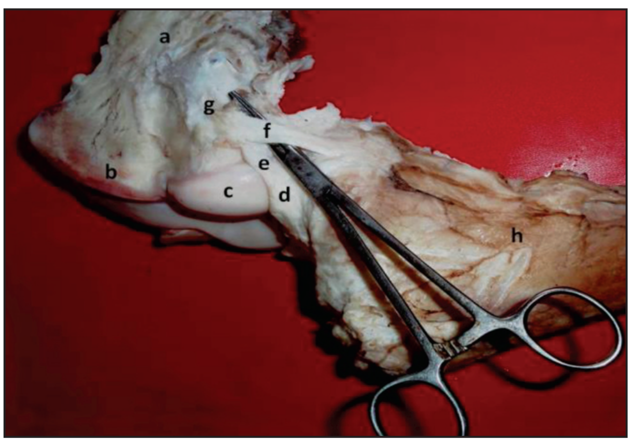

Fig 6. Gross anatomy of right stifle joint medial view II (joint capsule and patella removed).
(a) Femur, (b) Medial trochlear ridge, (c) Medial condyle of femur, (d) Medial meniscus, (e) Attachment of medial meniscus to medial epicondyle, (f) Medial collateral ligament, (g) Medial epicondyle (h) Tibia.

Menisci (Singular Meniscus)

There were two menisci, the lateral and the medial meniscus which act as cushions in the femoro-tibial articulation (Fig 1). These were almost crescent shaped, medial meniscus being somewhat more round and larger than the lateral one. These menisci were kept in place by various meniscal ligaments described as follows:

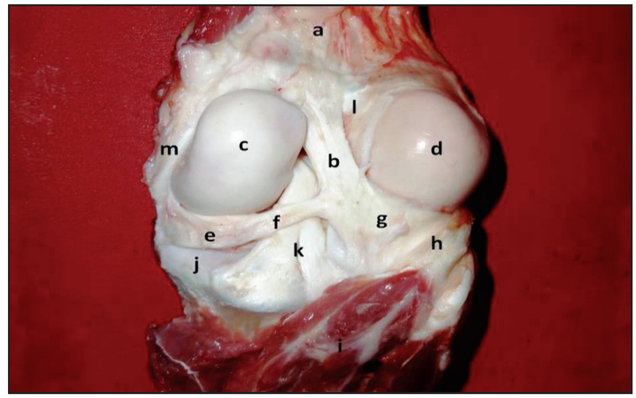

Fig 7. Gross anatomy of right stifle joint caudal view (joint capsule and patella removed).
(a) Femur, (b) Meniscofemoral ligament, (c) Medial condyle of femur, (d) Lateral condyle of femur, (e) Medial meniscus, (f) Ligament connecting menisci, (g) Lateral meniscus, (h) Popliteus muscle (origin), (i) Popliteus muscle, (j) Medial condyle of tibia, (k) Caudal cruciate ligament, (l) Cranial cruciate ligament, (m) Medial collateral ligament.

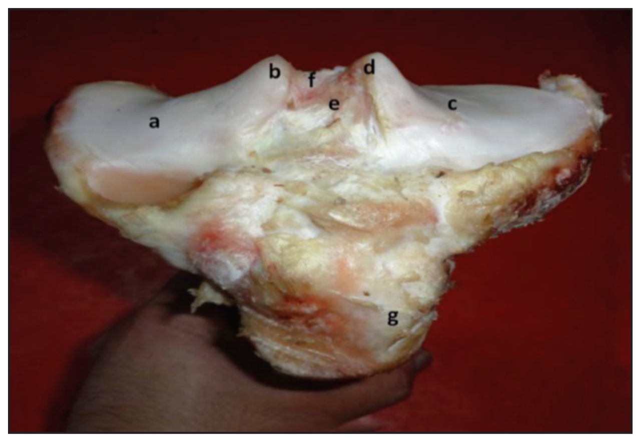

Fig 8. Gross anatomy of articular surfaces of right tibia (cranio dorsal view).
(a) Lateral condyle of tibia, (b) Lateral intercondylar tubercle, (c) Medial tibial condyle, (d) Medial intercondylar tubercle, (e) Cranial intercondylar area, (f) Caudal intercondylar area, (g) Tibial tuberosity.

Lateral Meniscus

It was **cranially** attached to the intercondylar area of tibia (Fig 1) and caudally attached to the caudal aspect of femur by meniscofemoral ligament (Fig 7).

Medial Meniscus

It was **cranially** attached to the intercondylar area of the tibia (Fig 1) and caudally attached to the caudal intercondylar area of femur and to the lateral meniscus over the caudal cruciate ligament (Fig 7).

It was medially attached to the origin of cranial cruciate ligament (Fig 1) and medial femoral epicondyle (Fig 6) and proximally and cranially to the medial collateral ligament (Fig 5).

II Morphometric Study

Morphometric study include the measurement of ligaments and important anatomical structures in terms of their dimensions *viz.* length, width, thickness etc. These data are presented in table 1.

Discussion

The stifle joint is a compound synovial joint having femorotibial (condylar joint) and femoropatellar (sellar joint) articulation. The patella is elongated with blunt base and pointed apex (apex directed distally). It is nearly congruent and articulate with femoral trochlea. The trochlea had a gliding groove with lateral and medial ridges. The lateral ridge is longer (evidenced by morphometric study) and prominent. These findings were in consonance with the findings of Smuts and Bezuidenhout (1987), Goldblatt and Richmond (2003), Dwek and Chung (2008), Siddiqui and Telfah (2010) and Fahmy *et al* (2011). No accessory cartilage was evidenced and the finding was in accordance to Krishnamurthy *et al* (1992). However, Manefield and Tinson (1997) stated that upward fixation of patella in camel denoted a tendency for the well developed fibrocartilage hook on the patellar border to be caught on the medial trochlear protuberance.

The stability of femopropatellar joint depends upon the shape and extension of the femoral trochlea which could provide a surface for patellar motion. The joint is also supported by various ligaments, thick fascia, musculature and their tendons. These findings were supported by Dwek and Chung (2008), Goldblatt and Richmond (2003), Neyret *et al* (2002) and Simon *et al* (2000).

The middle patella ligament is well developed patellar ligament which is in accordance to the studies of Smuts and Bezuidenhout (1987) and Siddiqui and Telfah (2010).

The lateral patellar ligament is represented by the fibres running between the lateral epicondylar region of femur and distolateral surface of patella. The ligament is also found to be associated with insertion of muscle gluteobiceps on patella and runs along with it distally to end at cranial tibial tuberosity. These findings were supported by Smuts and Bezuidenhout (1987) and Siddiqui and Telfah (2010).

The medial patellar ligament could not be evidenced. There was a ligament like strap originating from the muscle fascia of the medial aspect running between the medial femoral epicondyle and tibial tuberosity. There is evidence of medial femoropatellar ligament extended between the medial epicondyle of femur and the medial aspect of patella close to the mid. These findings are in consonance with findings of Krishnamurthy *et al* (1979), Smuts and Bezuidenhout (1987), Al-Ani (2004) and Siddiqui and Telfah (2010). They described it as a poorly defined medial femoropatellar ligament. The orientation of the medial femoro patellar ligament is different and it is present at an angle of 113.8° ± 1.93218°

Table 1. Morphometric data of various anatomical structures of stifle joint of camels (*Camelus dromedarius*).

S. No.	Particulars	Coefficient of variation (CV)	Values (Mean ± SD^b) (in cm)
1.	**Femoro-Patellar ligaments**		
	(a) Lateral Femoropatellar ligament		
	Length	1.764677	8.94 ± 0.15776
	Width	2.419535	4.11 ± 0.09944
	Thickness	9.621923	0.91 ± 0.08756
	(b) Lig. Patellae		
	Length	1.15155	15.96 ± 0.18379
	Width	2.336529	4.71 ± 0.11005
	Thickness	6.162583	1.28 ± 0.07888
	(c) Lig. Femoropatellar Mediale		
	Length	1.412131	11.66 ± 0.16465
	Width	5.250499	1.84 ± 0.09661
	Thickness	11.73631	0.88 ± 0.10328
2.	**Femoro-tibial ligaments**		
	(a) Medial Collateral Lig.		
	Length	2.84429	8.58 ± 0.24404
	Width	3.977162	2.07 ± 0.08233
	Thickness	4.689766	1.03 ± 0.0483
	(b) Lig. Cruciatum Craniale		
	Length	3.675317	4.66 ± 0.17127
	Width	6.684836	1.18 ± 0.07888
	Thickness	3.927202	1.23 ± 0.0483
	(c) Lig. Cruciatum Caudale		
	Length	2.220578	5.2 ± 0.11547
	Width	13.10514	1.57 ± 0.20575
	Thickness	7.052687	1.41 ± 0.09944
3.	**Ligaments of Menisci**		
	(I) Lateral Menisci		
	(a) Cranial Attachment		
	Length	4.072028	3.67 ± 0.14944
	Width	8.395427	1.13 ± 0.09487
	Thickness	15.05847	0.91 ± 0.13703

	(b) Lig. Menisco Femoral		
	Length	2.368912	9.13 ± 0.21628
	Width	4.451705	2.32 ± 0.10328
	Thickness	8.032982	1.09 ± 0.08756
	(II) Medial Meniscus		
	(a) Cranial Attachment		
	Length	3.458562	4.19 ± 0.14471
	Width	7.036518	1.17 ± 0.08233
	Thickness	11.71214	0.9 ± 0.10541
	(b) Caudal Attachment		
	Length	3.525821	7.2 ± 0.25386
	Width	6.588638	2.03 ± 0.13375
	Thickness	12.90746	1.02 ± 0.13166
4.	**Angle between middle patellar and medial femoro patellar lig. (in degree)**	1.697877	113.8 ± 1.93218
5.	**Angle between meniscofemoral and lig. connecting menisci caudally (in degree)**	2.136616	82.7 ± 1.76698
6.	**Menisci**		
	(I) Lateral		
	(a) Greater Curvature	2.541641	8.59 ± 0.21833
	(b) Lesser Curvature	2.713741	3.56 ± 0.09661
	(c) Max. Thickness	5.21829	2.06 ± 0.1075
	(d) Width From Centre	4.973474	2.13 ± 0.10593
	(II) Medial		
	(a) Greater Curvature	1.069014	10.62 ± 0.11353
	(b) Lesser Curvature	2.786148	4.54 ± 0.12649
	(c) Max. Thickness	5.483718	1.73 ± 0.09487
	(d) Width From Centre	4.750448	2.23 ± 0.10593
7.	**Patella**		
	(I) Length		
	(a) Greater Curvature	1.253474	15.71 ± 0.19692
	(b) Lesser Curvature	1.534022	9.62 ± 0.14757
	(II) Width		
	(a) Proximal	3.3789	4.51 ± 0.15239
	(b) Middle	2.768367	4.24 ± 0.11738
	(c) Distal	2.417706	5.25 ± 0.12693
	(III) Thickness		
	(a) Proximal	3.809706	4.47 ± 0.17029
	(b) Middle	2.472339	5.46 ± 0.13499
	(c) Distal	2.288371	5.15 ± 0.11785
8.	**Femoral Trochlea**		
	(I) Groove		
	(a) length	1.873364	7.57 ± 0.14181
	(b) width		
	(i) Proximal	2.206828	4.68 ± 0.10328

	(ii) Middle	2.983281	4.24 ± 0.12649
	(iii) Distal	2.297925	5.21 ± 0.11972
	(II) Trochlear Ridge Length		
	(a) Medial	1.397409	9.66 ± 0.13499
	(b) Lateral	1.092912	10.74 ± 0.11738
9.	**Tibial condyles**		
	(I) Lateral		
	(a) Mediolateral Dimension	1.674473	6.78 ± 0.11353
	(b) craniocaudal Dimension	2.083271	5.16 ± 0.1075
	(II) Medial		
	(a) Mediolateral Dimension	2.030873	6.25 ± 0.12693
	(b) Craniocaudal Dimension	2.188044	6.83 ± 0.14944
10.	**Femoral condyles**		
	(I) Lateral		
	(a) Mediolateral Dimension	3.312693	4.51 ± 0.149071
	(b) craniocaudal Dimension	1.865402	7.17 ± 0.133749
	(II) Medial		
	(a) Mediolateral Dimension	3.068328	4.66 ± 0.142984
	(b) Craniocaudal Dimension	2.042206	6.71 ± 0.137032

(a) Lig.- ligament
(b) SD- Standard Deviation

with the middle patellar ligament as evidenced by morphometric study.

Krishnamurthy *et al* (1992) revealed absence of medial patellar ligament in camel. However, due to similarities in texture as well as in location, the tendinous structure of the deep fascia is often mistaken for the medial patellar ligament.

Manefield and Tinson (1997) stated that the camels did not have 3 patellar ligaments as is seen in equine and the bovine, but rather a diffused band of fibrous tissue which covers the muscles on the medial aspect and inserted into the cranial tibial tuberosity.

The lateral and medial femoral condyles of femur and tibia were found nearly congruent at their respective articular surfaces of tibia. The intercondylar fossa of femur had depressions for the attachment of ligaments. The medial epicondyle had a prominence while the lateral epicondyle was relatively smooth. The fossa extensoria was deep whereas, fossa *m. poplitei* caudal to it was relatively shallow. The lateral condyle of tibia was roughly trapezoid in shape while medial condyle was larger and more rounded in shape. Margins of both condyles ended at respective intercondylar tubercle. The medial intercondylar tubercle was slightly higher in position than its lateral counterpart. There were depressions in the caudal intercondylar area for the attachment of ligaments. There was a depression between the lateral tibial condyle and the anterior tibial tuberosity. The anterior tibial tuberosity was very well developed, irregular and directed craniodorsally. It was indented along its proximal surface to form a short sulcus. There was a shallow transverse depression distal to the latter. Similar findings were documented by Smuts and Bezuidenhout (1987).

Among collateral ligaments, only medial was evidenced and lateral was absent. Medial collateral ligament traversed from the medial femoral epicondyle to the medial proximal aspect of the tibia. There was evidence of two well developed cruciate ligaments i.e. cranial and caudal cruciate ligament found intra articularly within the joint capsule. The cranial cruciate ligament had origin from the cranial intercondylar area of tibia and inserted on the lateral intercondylar surface of femur. The caudal cruciate ligament had origin from the caudal intercondylar area of the tibia and had two insertions i.e. one on the cranial surface of the medial intercondylar area of femur and another attached laterally to it. Similar communications had been reported by Smuts and Bezuidenhout (1987).

Rooster *et al* (2006) in their study on the cruciate ligament concluded that the cranial cruciate ligament control cranial drawer motion, whereas the caudal cruciate ligament act as a major stabiliser against caudal motion. Furthermore, the latter ligament was considered to fine tune normal stifle kinetics. Goldblatt and Richmond (2003) stated that the bony architecture of the femur, patella and tibia contribute to the stability of the stifle joint, along with static and dynamic restraints of the ligaments, capsule and muscular crossing the joint. Similar conclusions might be drawn from present study.

Two crescent shaped menisci, the lateral and medial meniscus which act as cushions in the femoro-tibial articulation were evidenced along with their attachments. These findings are in consonance with the findings of Smuts and Bezuidenhout (1987).

Uddin *et al* (2009) conducted a study on cattle aimed to determine the accurate location of giving incision for medial patellar desmotomy. They analysed the measurements of patellar ligaments in stifle joint of 50 indigenous and 50 crossbred slaughtered cattle. Similarly, morphometric studies were included in present study measured in 10 stifle joints collected from fresh cadavers. Descriptive statistics were given as Mean ± SD (standard deviation) and coefficient of variation was also calculated to show variability of a particular dimension. The morphometric study could be found as a useful reference for further studies.

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