Article published online: 2022-06-27

Computed Tomographic Measurements of the Sulcus Angle of the Femoral Trochlea in Small-Breed Dogs with and without Medial Patellar Luxation

Akari Sasaki[1,*] Yuki Hidaka[2,*] Manabu Mochizuki[1,2] Muneki Honnami[2]

[1] Laboratory of Veterinary Emergency Medicine, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan
[2] Veterinary Medical Center, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan

Address for correspondence Muneki Honnami, PhD, DVM, Veterinary Medical Center, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan (e-mail: m.honnami@gmail.com).

Vet Comp Orthop Traumatol 2022;35:314–320.

Abstract

Trochleoplasty is often performed in dogs with medial patellar luxation (MPL); however, the current guidelines on when to perform a trochleoplasty in dogs are vague. The sulcus angle (SA) is used to assess the femoral trochlear morphology in humans. The aim of this study is to describe a method to measure the SA and other parameters of trochlea morphology in dogs using computed tomography. First, we searched for a suitable measuring location for the SA. Transverse images of the femurs were obtained as perpendicular planes to the tangent of the femoral trochlea which was 0 to 60 degrees (every 5 degrees) to the anatomical axis of the femur. The deepest point of the femoral trochlea was found in the transverse images perpendicular to the tangent of the femoral trochlea which was at 15 degrees to the anatomical axis of the femur. The SA and the other parameters of femoral trochlea morphology were measured at the deepest point of the femoral trochlea. The SA of the stifle joints with grade 3 and 4 MPL was significantly higher than the SA of stifle joints not affected by MPL. There was no significant difference in the SA between dogs affected by grade 1 and 2 MPL and dogs not affected by MPL. Further studies are needed to establish whether the SA can be used as selection criteria for trochleoplasty.

Keywords
- ► sulcus angle
- ► dogs
- ► femoral trochlea
- ► patellar luxation
- ► computed tomography

Introduction

Medial patellar luxation (MPL) is one of the most common orthopaedic diseases in dogs.[1–5] There are several surgical options for the treatment of MPL, including trochleoplasty, which is a treatment method for shallow femoral trochlea. The aim of trochleoplasty is to manage patellar luxation by deepening the trochlear groove.[6–8] However, the current guidelines on when to perform a trochleoplasty in dogs are vague. The general recommendation is to perform a trochleoplasty when the femoral trochlea is flattened; however, the morphology of the femoral trochlea has not been accurately described neither in skeletally normal dogs nor in dogs with luxating patella.[5,9]

In human medicine, the femoral trochlear morphology can be evaluated by radiography or computed tomography (CT).[10–12] The sulcus angle (SA) is a radiographic parameter used to assess the femoral trochlear morphology in patients with patellar instability.[13–15] The SA is the angle formed by lines connecting from the most posterior point of the femoral trochlea and the most anterior points of the medial and lateral trochlear ridges. Sulcus angles of 145 degrees or

* *These authors contributed equally to this work.*

received
May 24, 2021
accepted after revision
April 6, 2022
published online
June 27, 2022

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

DOI https://doi.org/10.1055/s-0042-1749151.
ISSN 0932-0814.

greater indicate trochlear dysplasia in humans (shallow femoral trochlea).[16]

The first two aims of the present study are to describe CT measurement of the SA in dogs and to assess whether there is a difference in the SA between skeletally normal dogs and dogs affected by MPL. In order to elucidate what kind of morphological changes are present in the trochlea of dogs affected by MPL, we also measured several other parameters of femoral trochlear morphology in dogs: medial trochlear slope (MTS), lateral trochlear slope (LTS), medial trochlear ridge height (MRH), lateral trochlear ridge height (LRH), height of the middle portion of the femoral trochlea (HMF) and the height of the caudal portion of the femoral trochlea (HCF). The parameters are measured on CT scans of skeletally normal dogs and dogs affected by MPL. The final aim of this study is to assess whether the above parameters are different in skeletally normal dogs and in dogs affected by MPL.

Materials and Methods

All diagnostic procedures, including CT and anaesthesia, were conducted with the client's consent accordingly.

Measurement of the Sulcus Angle

To determine the suitable measurement location of the femoral trochlear morphology, we took CT images of both stifle joints of skeletally normal dogs and dogs affected by MPL. As a representative of skeletally normal dogs, small-breed dogs without skeletal disorders that underwent CT examination at Veterinary Medical Center of the University of Tokyo from July 2017 to May 2020 were included in the study. Dogs diagnosed with MPL on palpation and that underwent CT examination at Veterinary Medical Center of the University of Tokyo from September 2013 to July 2020 were included in the study as dogs affected by MPL. The MPL of each stifle joint was graded as follows[9] Grade 1—the patella could be manually luxated but it returned to the normal position when released; Grade 2—the patella luxated with stifle flexion or manual manipulation and remained luxated until stifle extension or manual replacement occurred; Grade 3—the patella luxated continually and could be manually replaced but it would reluxate spontaneously when manual pressure was removed; Grade 4—the patella luxated continually and could not be replaced manually. Stifle joints not affected by MPL which were contralateral to the stifle joints affected by MPL were classified as Grade 0. The dogs were first sedated (medetomidine hydrochloride 20 µg/kg, intravenous (iv); Kyoritsu Seiyaku Corporation, Tokyo Japan, and midazolam 0.3 mg/kg, iv; Fuji Pharma Co., Ltd., Tokyo, Japan) or anaesthetized (propofol 3 mg/kg, iv for the induction of anaesthesia and isoflurane for the maintenance of anaesthesia; MSD Animal Health, Tokyo, Japan), and then they underwent CT examinations (Aquilion PRIME, Toshiba Medical Systems Corp, Tokyo, Japan, 0.5 mm of slice thickness). We visualized the CT images using a multiplanar reconstruction using an image processing software (Osirix, Newton Graphics, Inc., Hokkaido, Japan). The transverse images of the femur were obtained as perpendicular planes to the tangent of the femoral trochlea which was 0 to 60 degrees (every 5 degrees) to the anatomical axis of the femur (►Fig. 1). The SA was measured as the angle formed by lines connecting from the caudal point of the femoral trochlea and the most cranial points of the medial and lateral trochlear ridges (►Fig. 2). The SA measured in perpendicular planes to the tangent of the femoral trochlea, which was over 60 degrees to the anatomical axis of the femur, was not included in this study because they reflected the depth of the intercondylar fossa rather than the depth of femoral trochlea. All the measurements were conducted by a single veterinary surgeon. Among all the measured transverse images, we set the standard plane based on the deepest point of the femoral trochlea: transverse images of the femur perpendicular to the tangent of the femoral trochlea which was 15 degrees to the anatomical axis of the femur. The SA at the standard transverse images for stifle joints with MPL grade 0 to 4 was compared with that for the skeletally normal stifle joints using Kruskal–Wallis test followed by the Steel test.

Measurement of Parameters of Femoral Trochlea Morphology

In order to compare the femoral trochlear morphology of skeletally normal dogs and dogs affected by MPL, six parameters were measured at the standard transverse images of the femur (►Fig. 2) A baseline was drawn as a tangent to the caudal condyles on the transverse images. The MTS and LTS were measured as angles between the facet inclination and baseline. The medial trochlear ridge height (MRH) and LRH were measured as the height between the most cranial points of the medial and lateral trochlear ridges and the most caudal point of the femoral trochlea. The HMF was measured as the height between the most caudal point of the femoral trochlea and the intercondylar fossa. Height of the HCF was measured as the height between the intercondylar fossa and the baseline. All the measurements were conducted by a single veterinary surgeon. The values of each parameter for stifle joints affected by MPL grade 0 to 4 were compared with those for the skeletally normal stifle joints using Kruskal–Wallis test followed by the Steel test.

All the statistical analyses were conducted using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria).[18] The results are presented as the mean $\pm$ standard deviation. Statistical significance was set at $p < 0.05$.

Results

Measurement of the Sulcus Angle

As skeletally normal stifle joints, 26 stifle joints of 13 dogs (4 females, 4 neutered females, 3 males and 2 neutered males) were included in this study. The mean age was 101.4 ± 61.0 months old and the mean body weight was 3.6 ± 1.2 kg. The breeds of the dogs were Toy-poodle ($n = 5$), Pomeranian ($n = 5$) and Chihuahua ($n = 3$). As stifle joints affected by MPL, 40 stifle joints of 20 dogs (6 females, 7 neutered females, 5 males and 2 neutered males) were included in this study. The mean age was

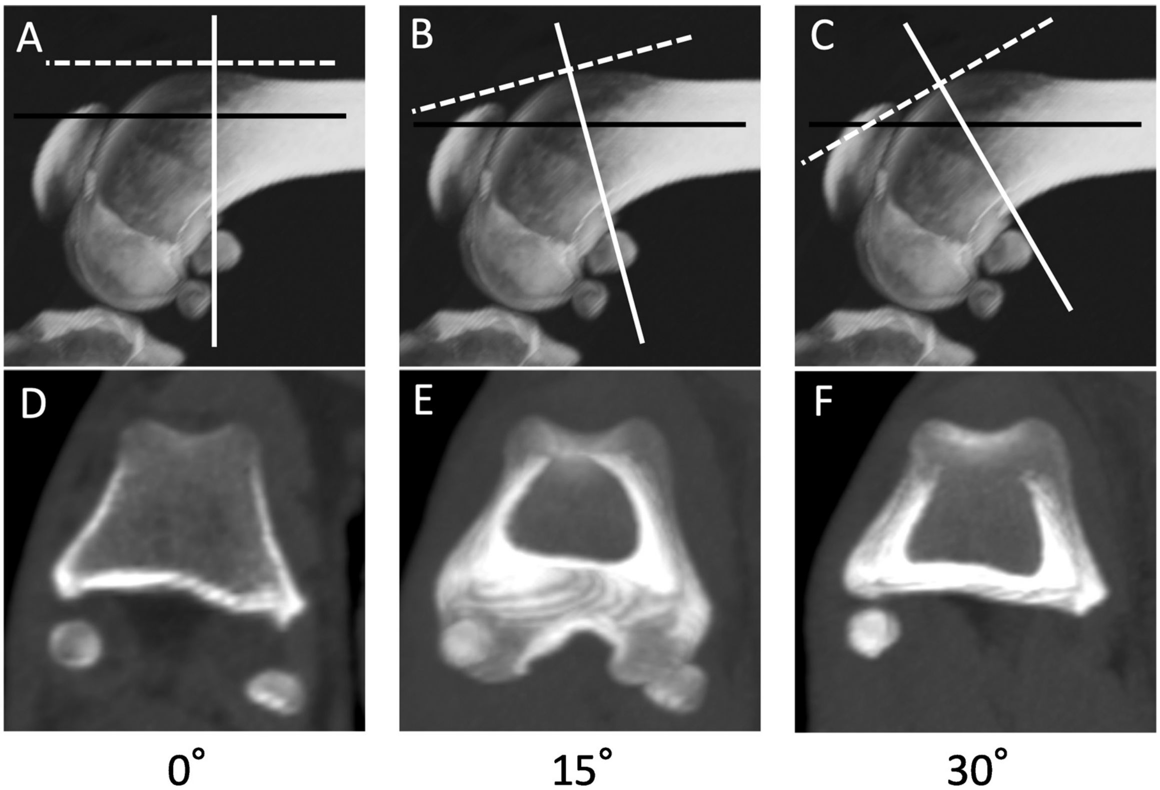

Fig. 1 The method of measuring the sulcus angle (SA) in dogs. (**A–C**) The lateral views of the distal femur. The black lines represent the anatomical axis of the femur. White dotted lines represent tangents of the femoral trochlea (angles formed between the anatomical axis of the femur are 0 degrees for **A**, 15 degrees for **B** and 30 degrees for **C**). White solid lines are perpendicular to the white dotted lines. Transverse images were obtained containing a white solid line and parallel to the lines connecting the lateral condyles and medial condyles (**D–F** correspond to **A**, **B** and **C** respectively).

26.2 ± 25.6 months old and the mean body weight was 3.1 ± 1.5 kg. The breeds of the dogs were Toy-poodle ($n = 9$), Pomeranian ($n = 4$), Chihuahua ($n = 1$), Shiba ($n = 1$), Italian greyhound ($n = 1$) and mixed breed ($n = 4$). The numbers of the stifle joints in dogs affected by MPL classified as grade 0, 1, 2, 3 and 4 were 5, 1, 16, 8 and 10 respectively. ►**Fig. 3** shows the SA measured at each position in the stifle joints of skeletally normal dogs and dogs affected by MPL. The SA of the skeletally normal stifle joints was 139.2 ± 8.9 degrees when the tangent of the femoral trochlea was 0 degree to the anatomical axis of the femur and it reduced to 135.6 ± 8.0 degrees when the tangent of the femoral trochlea was 15 degrees to the anatomical axis of the femur. Thereafter, the SA increased, reaching 149.1 ± 7.5 degrees when the tangent of the femoral trochlea was 60 degrees to the anatomical axis of the femur. The SA of the dogs affected by MPL was graphed as a curve similar to that of skeletally normal dogs, with a lowest value of 141.9 ± 13.1 degrees when the tangent of the femoral trochlea was 15 degrees to the anatomical axis of the femur. At the standard transverse images, the SA of the stifle joints affected by grade 3 and 4 MPL was significantly higher than those of the skeletally normal stifle joints (►**Table 1**).

Measurement of Parameters of Femoral Trochlea Morphology

►**Table 1** lists the results of each parameter. The MTS and LTS of the stifle joints affected by grade 4 MPL were significantly lower than that of skeletally normal stifles. The MRH of the stifle joints affected by grade 3 and 4 MPL was significantly lower than those of the skeletally normal stifle joints. The LRH of the stifle joints affected by grade 4 MPL was significantly lower than that of the skeletally normal stifle joints. There were no significant differences in the HMF and HCF between the skeletally normal stifle joints and the stifle joints affected by MPL.

Discussion

For both skeletally normal dogs and dogs affected by MPL, the lowest value of the SA was measured in the transverse images perpendicular to the tangent of the femoral trochlea which was 15 degrees to the anatomical axis of the femur. To standardize the measuring location, we used these images to assess the femoral trochlear morphology. Similar results were obtained for the SA of the femoral trochlea of humans. Nha and colleagues measured the SA of the femoral trochlea of humans when the transverse images of the femur perpendicular to the tangent of the femoral trochlea were 8.1, 21.7, 66.1 and 94.8 degrees to the axis of the femur.[19] The lowest value of the SA was found at the transverse images of the femur perpendicular to the tangent of the femoral trochlea which was 21.7 degrees to the anatomical axis of the femur.[19] The standardized measuring location in the present study was relatively proximal to the femoral trochlea. Nicetto and

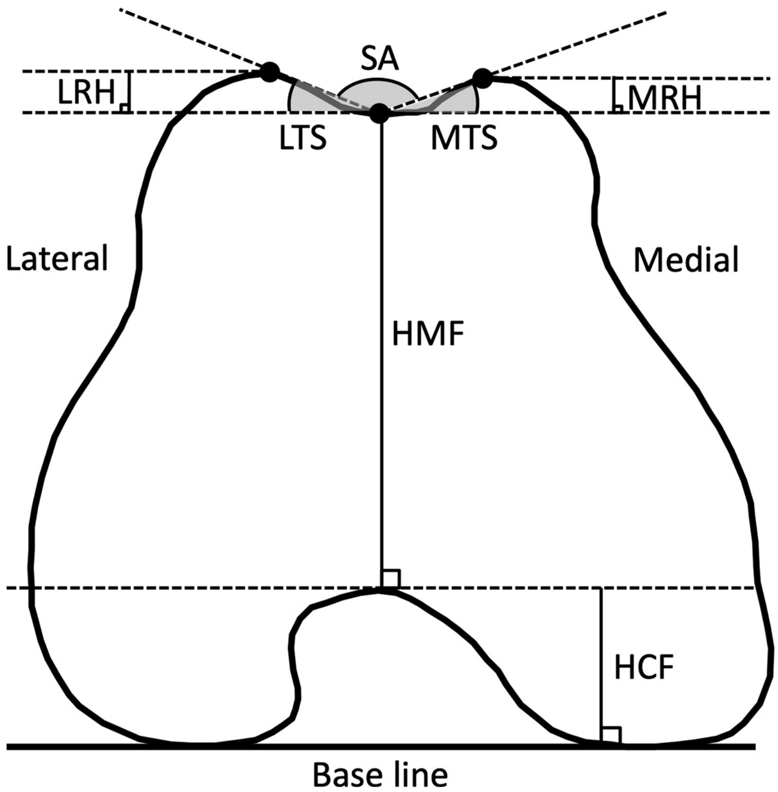

Fig. 2 Seven parameters of the femoral trochlear morphology were measured. The baseline was drawn as a tangent to the caudal condyles. Black spots: the most cranial point of the trochlear ridges and the most caudal point of the femoral trochlea. HCF, height of caudal portion of the femoral trochlea; HMF, height of middle portion of the femoral trochlea; LRH, lateral trochlear ridge height; LTS, lateral trochlear slope; MRH: medial trochlear ridge height; MTS: medial trochlear slope; SA, sulcus angle.

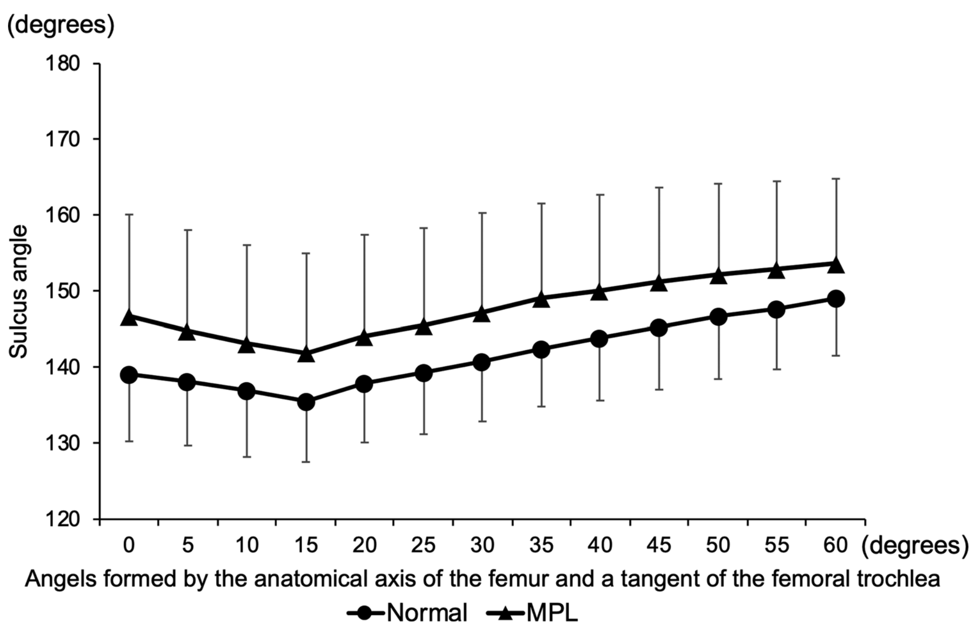

Fig. 3 The sulcus angle (SA) of the femoral trochlea for the skeletally normal stifle joints and the stifle joints in dogs affected by medial patellar luxation (MPL). The SA was measured in transverse images which are perpendicular to the tangent of the femoral trochlea which was 0 to 60 degrees (every 5 degrees) to the anatomical axis of the femur. The means and + standard deviation (SD) (for the stifle joints in dogs affected by MPL) or − SD (for the skeletally normal stifle joints) are shown.

Table 1 The values of seven parameters of femoral trochlear morphology

Parameters	Skeletally normal stifle joints ($n=26$)	Stifle joints in dogs affected by MPL				
		Grade 0 ($n=5$)	Grade 1 ($n=1$)	Grade 2 ($n=16$)	Grade 3 ($n=8$)	Grade 4 ($n=10$)
SA (degree)	135.6 ± 8.0	132.5 ± 3.0	127.8	134.3 ± 7.0	147.1 ± 10.1[b]	155.9 ± 12.9[b]
MTS (degree)	21.2 ± 4.8	20.2 ± 2.1	26.2	21.3 ± 6.1	15.0 ± 8.3	10.8 ± 11.0[a]
LTS (degree)	23.4 ± 5.9	25.8 ± 4.2	21.1	24.1 ± 3.2	20.7 ± 5.5	13.7 ± 7.4[b]
MRH (mm)	1.2 ± 0.4	1.3 ± 0.3	1.3	1.2 ± 0.4	0.6 ± 0.4[a]	0.4 ± 0.5[b]
LRH (mm)	1.2 ± 0.3	1.4 ± 0.2	1.1	1.2 ± 0.3	1.1 ± 0.4	0.6 ± 0.3[b]
HMF (mm)	9.8 ± 1.0	10.7 ± 1.5	8.5	10.1 ± 1.5	9.2 ± 0.7	8.9 ± 2.3
HCF (mm)	3.8 ± 0.5	3.7 ± 0.3	3.9	4.1 ± 0.9	3.6 ± 0.5	3.7 ± 0.5

Abbreviations: HCF, height of caudal portion of the femoral trochlea; HMF, height of middle portion of the femoral trochlea; LRH, lateral trochlear ridge height; LTS, lateral trochlear slope; MPL, medial patellar luxation; MRH, medial trochlear ridge height; MTS, medial trochlear slope; SA, sulcus angle.
Note: The mean ± standard deviation values are shown. Significant differences compared with the skeletally normal stifle joints are shown with superscript letters (Kruskal–Wallis test followed by the Steel test).
[a]$p < 0.05$.
[b]$p < 0.01$.

colleagues measured the femoral trochlear depth in dogs without stifle disorders, and also found that the deepest point of the femoral trochlea was located in the proximal part of the femoral trochlea.[20] Considering that the articular congruence of the proximal aspect of the patellofemoral joint is thought to be crucial for patellar instability in both human and veterinary medicine,[21,22] measuring the femoral trochlear morphology on the standardized measuring location in the present study was appropriate for the evaluation of the femoral trochlear morphology in dogs.

We found significant differences in the SA, MTS, LTS, MRH and LRH between the skeletally normal stifle joints and the stifle joints affected by grade 4 MPL. However, there were no significant differences between the HMF and HCF. For humans, the trochlear ridge height of patients with patellar luxation is also lower than that of normal subjects, and as a consequence, the SA of patients is larger than that of normal subjects.[11] Theoretically, a high SA value and low MTS, LTS, MRH and LRH values can be thought to appear if both the bottom of the femoral trochlea is raised and the trochlear ridge height decreases. However, there were no significant differences in the HMF and HCF between the skeletally normal stifle joints and the stifle joints affected by MPL. Considering this, high SA values and low MTS, LTS, MRH and LRH values found in the stifle joints affected by MPL grade 4 were assumed to be mainly related to a decrease in the MRH and LRH. There were significant differences in the SA and MRH between the skeletally normal stifle joints and the stifle joints affected by grade 3 MPL. This result indicates that the medial trochlear ridge is particularly affected by a decrease in contact pressure by the patella. The trochlear ridge height and the SA also correlate with the severity of trochlear dysplasia in humans.[11,15]

We found no significant difference between dogs affected by grade 1 to 2 MPL and skeletally normal dogs for all the parameters measured. The reason for this finding is not known. One could speculate that this could reflect the presence or absence of the contact pressure exerted by the patella on the femoral trochlea during development. In stifle joints affected by grade 1 to 2 MPL, the patella is located within the femoral trochlea most of the time. This could be the reason for normal development of femoral trochlea morphology. On the other hand, in stifle joints affected by grade 3 to 4 MPL, the patella is located outside the femoral trochlea most of the time. It has been demonstrated that the lack of contact pressure exerted by the patella can lead to the development of a shallow trochlea in some studies using experimental rabbit and rat models.[23,24] A shallow trochlea is associated with an increase in the SA and a decrease in other parameters of the femoral trochlear morphology. Considering there was also no significant difference between the stifle joints classified as grade 0 and the skeletally normal stifle joints in the present study, it can be inferred that the shallow trochlear morphology is formed as a consequence of MPL. Further studies looking into aetiopathogenesis of MPL in dogs would be needed to clarify this.

Trochleoplasty has been performed for many dogs affected by MPL to correct the femoral trochlear morphology.[1,7,8] On the contrary, previous studies have suggested a correlation between trochleoplasty and osteoarthritis and the inessentiality of trochleoplasty for all of the dogs affected by MPL.[25–27] All the trochleoplasty techniques involve injury to the articular cartilage to some extent; therefore, the procedure should be performed only when it is strictly necessary.[17,28] As the degree of abnormalities in the femoral trochlear morphology varies from case to case, appropriate evaluation methods for the femoral trochlear morphology in dogs are required for the application of individualized treatment for each dog affected by MPL. Properly selecting patients requiring trochleoplasty could improve treatment outcomes or minimize surgical trauma to the stifle joint accordingly.

Small-breed dogs are known to be more commonly affected by MPL than large-breed dogs.[4,29] We selected Toy-poodle, Pomeranian and Chihuahua as the skeletally normal subjects as these breeds have been reported to be susceptible to MPL.[1,7,30,31] Further studies should be performed for large-breed dogs. One of the major limitations of our study was that it was a single-centre study with a small sample size. Moreover, because our centre is a secondary care hospital, the population of dogs with grade 1 MPL was particularly small. A multi-centre study with a larger population would provide better insights.

Computed tomographic examinations enable a more accurate measurement of the femoral trochlear morphology than radiographic examinations because of their ability to image the correct geometric location. On the contrary, they have a critical disadvantage that they can only reflect osseous structures.[32] In human medicine, it is reported that there are differences between the SA measured for the articular cartilage surface and for the contour of subchondral bone.[33] Measuring methods which can reflect the articular cartilage surface, such as ultrasonography or magnetic resonance imaging, would enable more accurate evaluation of the femoral trochlear morphology. Computed tomographic examinations have more problems that they require sedation or general anaesthesia and are costly and time consuming in veterinary medicine.[32] In order to utilize the present results for screening tests for the judgement of surgical treatments of MPL, more convenient measuring methods should be developed in future studies.

The fact that the deepest point of the femoral trochlea was consistent between the skeletally normal stifle joints and the stifle joints affected by MPL showed the possibility of the objective measurement of the femoral trochlear morphology in dogs at the unified measuring location. Further studies are needed to assess whether the SA and the other parameters of trochlear morphology evaluated in this study can be used as selection criteria to decide whether dogs affected by patellar luxation should undergo a trochleoplasty or not.

Authors' Contributions

A.S. and Y.H. were involved in conception of study, study design, acquisition of data, data analysis and interpretation, drafting of manuscript and approval of submitted manuscript.

M.M. conceptualized the study, revised the manuscript and provided approval of submitted manuscript. M.H. was involved in conception of study, study design, acquisition of data, data analysis and interpretation, revising of manuscript and approval of submitted manuscript.

Funding

None.

Conflict of Interest

None declared.

Acknowledgment

We thank the staff of Veterinary Medical Center of The University of Tokyo for supporting data collection and Editage for English language editing.

References

1 Bosio F, Bufalari A, Peirone B, Petazzoni M, Vezzoni A. Prevalence, treatment and outcome of patellar luxation in dogs in Italy. A retrospective multicentric study (2009-2014). Vet Comp Orthop Traumatol 2017;30(05):364–370

2 O'Neill DG, Meeson RL, Sheridan A, Church DB, Brodbelt DC. The epidemiology of patellar luxation in dogs attending primary-care veterinary practices in England. Canine Genet Epidemiol 2016; 3:4

3 Wangdee C, Leegwater PAJ, Heuven HCM, et al. Prevalence and genetics of patellar luxation in Kooiker dogs. Vet J 2014;201(03): 333–337

4 Bound N, Zakai D, Butterworth SJ, Pead M. The prevalence of canine patellar luxation in three centres. Clinical features and radiographic evidence of limb deviation. Vet Comp Orthop Traumatol 2009;22(01):32–37

5 Johnston SA, Tobias KM. Veterinary Surgery: Small Animal Expert Consult. 2nd edition. St. Louis: Elsevier; 2017

6 Cashmore RG, Havlicek M, Perkins NR, et al. Major complications and risk factors associated with surgical correction of congenital medial patellar luxation in 124 dogs. Vet Comp Orthop Traumatol 2014;27(04):263–270

7 Wangdee C, Theyse LFH, Techakumphu M, Soontornvipart K, Hazewinkel HAW. Evaluation of surgical treatment of medial patellar luxation in Pomeranian dogs. Vet Comp Orthop Traumatol 2013;26(06):435–439

8 Arthurs GI, Langley-Hobbs SJ. Complications associated with corrective surgery for patellar luxation in 109 dogs. Vet Surg 2006;35(06):559–566

9 Roush JK. Canine patellar luxation. Vet Clin North Am Small Anim Pract 1993;23(04):855–868

10 Merchant AC, Mercer RL, Jacobsen RH, Cool CR. Roentgenographic analysis of patellofemoral congruence. J Bone Joint Surg Am 1974; 56(07):1391–1396

11 Brattstroem H. Shape of the intercondylar groove normally and in recurrent dislocation of patella: a clinical and X-ray anatomical investigation. Acta Orthop Scand Suppl 1964;68:1–148

12 Toms AP, Cahir J, Swift L, Donell ST. Imaging the femoral sulcus with ultrasound, CT, and MRI: reliability and generalizability in patients with patellar instability. Skeletal Radiol 2009;38(04): 329–338

13 Tecklenburg K, Dejour D, Hoser C, Fink C. Bony and cartilaginous anatomy of the patellofemoral joint. Knee Surg Sports Traumatol Arthrosc 2006;14(03):235–240

14 Tan SHS, Ibrahim MM, Lee ZJ, Chee YKM, Hui JH. Patellar tracking should be taken into account when measuring radiographic parameters for recurrent patellar instability. Knee Surg Sports Traumatol Arthrosc 2018;26(12):3593–3600

15 Davies AP, Costa ML, Shepstone L, Glasgow MM, Donell S. The sulcus angle and malalignment of the extensor mechanism of the knee. J Bone Joint Surg Br 2000;82(08):1162–1166

16 Dejour D, Le Coultre B. Osteotomies in patello-femoral instabilities. Sports Med Arthrosc Rev 2007;15(01):39–46

17 Di Dona F, Della Valle G, Fatone G. Patellar luxation in dogs. Vet Med (Auckl) 2018;9:23–32

18 Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. Bone Marrow Transplant 2013;48(03): 452–458

19 Nha KW, Papannagari R, Gill TJ, et al. In vivo patellar tracking: clinical motions and patellofemoral indices. J Orthop Res 2008;26 (08):1067–1074

20 Nicetto T, Longo F, Contiero B, Isola M, Petazzoni M. Computed tomographic localization of the deepest portion of the femoral trochlear groove in healthy dogs. Vet Surg 2020;49(06): 1246–1254

21 Salzmann GM, Weber TS, Spang JT, Imhoff AB, Schöttle PB. Comparison of native axial radiographs with axial MR imaging

for determination of the trochlear morphology in patients with trochlear dysplasia. Arch Orthop Trauma Surg 2010;130(03):335–340

22 Johnson AL, Probst CW, Decamp CE, et al. Comparison of trochlear block recession and trochlear wedge recession for canine patellar luxation using a cadaver model. Vet Surg 2001;30(02):140–150

23 Lu J, Wang C, Li F, Ji G, Wang Y, Wang F. Changes in cartilage and subchondral bone of femoral trochlear groove after patellectomy in growing rabbits. Orthop Surg 2020;12(02):653–660

24 Yang G, Li F, Lu J, et al. The dysplastic trochlear sulcus due to the insufficient patellar stress in growing rats. BMC Musculoskelet Disord 2019;20(01):411

25 Yoon DY, Kang BJ, Kim Y, et al. Degenerative joint disease after medial patellar luxation repair in dogs with or without trochleoplasty. J Vet Clin 2015;32:22–27

26 van der Zee JH. Lesions in canine stifle joints due to trochleoplasties as treatment for medial patellar luxation. J S Afr Vet Assoc 2015;86(01):1245

27 Linney WR, Hammer DL, Shott S. Surgical treatment of medial patellar luxation without femoral trochlear groove deepening procedures in dogs: 91 cases (1998-2009). J Am Vet Med Assoc 2011;238(09):1168–1172

28 Piermattei D, Flo G, DeCamp C. Brinker, Piermattei and Flo's Handbook of Small Animal Orthopedics and Fracture Repair. 4th edition. St. Louis: Saunders; 2006

29 Boge GS, Moldal ER, Dimopoulou M, Skjerve E, Bergström A. Breed susceptibility for common surgically treated orthopaedic diseases in 12 dog breeds. Acta Vet Scand 2019;61(01):19

30 LaFond E, Breur GJ, Austin CC. Breed susceptibility for developmental orthopedic diseases in dogs. J Am Anim Hosp Assoc 2002;38(05):467–477

31 Alam MR, Lee JI, Kang HS, et al. Frequency and distribution of patellar luxation in dogs. 134 cases (2000 to 2005). Vet Comp Orthop Traumatol 2007;20(01):59–64

32 Soler M, Murciano J, Latorre R, Belda E, Rodríguez MJ, Agut A. Ultrasonographic, computed tomographic and magnetic resonance imaging anatomy of the normal canine stifle joint. Vet J 2007;174(02):351–361

33 Tan SHS, Chng KSJ, Lim BY, et al. The difference between cartilaginous and bony sulcus angles for patients with or without patellofemoral instability: a systematic review and meta-analysis. J Knee Surg 2020;33(03):235–241

