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Clinical Characteristics of Sound Dogs with Medial Patellar Luxation

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Abstract : The purpose of this study is to identify clinical features of sound (non-lame) dogs with medial patellar luxation (MPL). Medical records of 72 dogs diagnosed with MPL were retrospectively reviewed. There were no significances in breed, sex, body weight, body condition score (BCS), osteoarthritis (OA) score, inclination of the femoral head angle (IFA), and mechanical medial proximal tibial angle (mMPTA) between sound and lame dogs, respectively. The mean age of sound dogs was significantly higher than that of lame dogs ($P < 0.05$), especially in MPL grade 3. The frequency of sound dogs with MPL grade 1 and 2 was 2.3 times higher than that of sound dogs with MPL grade 3 and 4 ($P < 0.05$). The anatomical lateral distal femoral angle (aLDFA) of sound dogs was significantly lower than that of lame dogs ($P < 0.05$). However, there were no statistical differences in aLDFA between sound and lame dogs in MPL grade 1, 2, and 4, except for MPL grade 3. This study suggests that in case of MPL grade 1 and 2, frequency of sound dogs is significantly high, and also that in MPL grade 3, if mean ± (standard deviation) age of the dogs is 7.4 ± 3.6 years old and the aLDFA is 105.6 ± 4.1 degrees, they are very highly possible to be sound dogs.

***Key words* :** medial patellar luxation, sound dog, anatomical lateral distal femoral angle.

Introduction

Medial patellar luxation (MPL) is an orthopedic disease that is defined as displacement of the patella from the trochlear groove and is a common cause of lameness in dogs (1,10,11,28).

Although the etiopathogenesis of MPL is not fully understood, it is considered to be either congenital or developmental (1,13,14,31). Certain deformities of the femur are associated with the development of MPL, such as femoral varus deformity and a shallow trochlear groove (9). In addition, angular and rotational deformities of the femur and tibia are hypothesized to cause abnormal stress in the stifle joint, which could account for degenerative changes, pain, and lameness (1,13,14,17). In some theories, a decrease in the angle of anteversion is thought to contribute to the development of MPL (1,31). These anatomical variations of the pelvic limbs consequently interfere with the mechanism of the quadriceps muscles and make it difficult to understand MPL (9).

Because of the multifactorial nature of MPL, it is difficult accurately to predict its clinical symptoms (1,13,14). One symptom, lameness, is not always observed in dogs with MPL and some dogs have lifelong occult MPL (28). A substantial number of dogs with MPL may show no clinical signs; therefore, these dogs may never have been admitted for evaluation (13,14).

There have been various studies on MPL associated with bone deformities and surgical methods (2,4,5,8,28-30,33). However, the features of dogs that were diagnosed with MPL without lameness have not been reported. Therefore, the aim of this study was to identify clinical features such as sex, age, body weight, body condition score (BCS), grade of patella luxation, osteoarthritis (OA) score, anatomical lateral distal femoral angle (aLDFA), inclination of the femoral head angle (IFA), and mechanical medial proximal tibial angle (mMPTA) in sound dogs with MPL.

Materials and Methods

Animals

The medical records of 124 dogs with MPL presenting to the Veterinary Medical Teaching Hospital of Konkuk University (VMTH-KU) between March 2015 and August 2017 were retrospectively reviewed. The patients with or without lameness were presented for diagnosis of medial patellar luxation. The exclusion criteria were dogs that underwent a previous patella surgery, had cranial cruciate ligament rupture, hip dysplasia, or other orthopedic or neurologic abnormalities. In an attempt to minimize variations in femoral and tibial joint angles, this study focused on six breeds that were frequently diagnosed with MPL and commonly seen at VMTH-KU: Pomeranian, Yorkshire Terrier, Maltese, Chihuahua, Poodle, and Shih-Tzu. Eventually, data were retrieved from 72 dogs that met the study criteria. The sound and lame groups were comprised of 42 and 30 dogs, respectively. Radiographs of 102 limbs with MPL were allocated into the sound (69 limbs) and lame (33 limbs) groups.

Clinical factors

General information obtained from the medical records included breed, sex, age, body weight, BCS, patella luxation grade, and lameness grade. Radiographs of limbs with MPL

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were evaluated for OA status and bone deformity.

The BCS was assessed to indicate the degree of obesity by using a five-point scale (18). Patellar luxation grades were assigned by flexing and extending the stifle joint (30). The degree of lameness was evaluated by the clinicians using a six-point numerical scale: degree of lameness 0, walks normally; 1, slight lameness; 2, obvious weight bearing lameness; 3, severe weight bearing lameness; 4, intermittent non weight bearing lameness; 5, continuous without weight bearing lameness (20). Gait was evaluated by visual and video recording under walking and trot. The gait analysis was conducted several times at the walking distance of more than 15 m. In cases in which the degree of lameness varied, the most severe score was recorded. The dogs were divided into two groups based on the presence or absence of lameness. The OA score was determined by the sum of the scores (each from 0 to 3; 0 = no degenerative changes were apparent, 1 = mild changes, 2 = moderate changes, 3 = severe changes) from 24 locations (for example, periarticular osteophytes lateral femoral condyle, periarticular osteophytes medial femoral condyle, osteophytes femoral intercondylar region, etc) on the hind limb on frontal and lateral plane radiographs (4).

After the clinical histories of sound dogs were analyzed, their physical findings were compared with those of lame dogs and it was determined whether there were differences between sound and lame dogs within each grade.

Pelvic limb alignment measurement technique

All angles were measured using a Digital Imaging and Communications in Medicine software image viewer (RadiAnt DICOM Viewer, version 1.1.8; Meixant, Poznan, Poland). The angular deformity was calculated using a previously reported standardized method of pelvic limb alignment measurement (17). Radiographs were performed with or without anesthesia.

aLDFA

The length of the femur was determined by the connection between the proximal aspect of the femoral neck and the proximal aspect of the intercondylar fossa. Along the femur, locations were marked corresponding to 33% and 50% of the femoral length. Through these two center points, the femoral anatomic axis was drawn. The distal stifle joint reference line was drawn to just contact the most distal aspects of the lateral and medial condyles of the femur. The aLDFA was the lateral angle formed between the distal stifle joint line and the anatomic axis of the femur in the frontal plane.

IFA

The IFA was formed by the anatomical axis of the femur and the femoral neck axis that connected the center of the femoral head and the point that bisected the femoral neck.

mMPTA

The mechanical tibia axis was the straight line connecting the center points of the tibial spines to the most distal aspect of the subchondral bone of the distal intermediate tibial ridge. The proximal tibial joint line was the line connecting the most distal aspect of the subchondral concavities of the medial and lateral tibial condyles. The mMPTA was measured at the intersection of the tibial mechanical axis and the proximal tibial joint line.

Statistical analysis

All statistical analyses were performed with the use of a computer software program (Statistical Package for the Social Sciences version 24.0 for Windows; IBM, Armonk, NY, USA). The statistical analysis of numerical data associated with multivariate factors was performed using the chi-squared test (χ^2 test) or Fisher's exact test. Odds ratios (ORs) were used to describe the magnitude of differences associated with each factor. The Kolmogorov-Smirnov test indicated that all continuous variables violated the normality assumption; hence, the Mann-Whitney U test was used to investigate statistical differences between sound and lame dogs. A logistic regression was performed to estimate the relationship between sound dogs and age, and the results are presented as 95% confidence intervals (CIs) and ORs. *P* values < 0.05 were defined as statistically significant.

Results

Breed

The breed distribution was presented in Table 1. The most common breeds among sound dogs in descending order were the Pomeranian (n = 10), Maltese (n = 9), Yorkshire terrier (n = 9), Chihuahua (n = 7), Poodle (n = 4), and Shih-Tzu (n = 3). Among lame dogs, the most common breeds in descend-

Table 1. Breed distribution between sound and lame dogs

Breed	Sound dogs	Lame dogs	Total	*P* value*
	Number (%)	Number (%)		
Chihuahua	7 (15.6%)	2 (6.7%)	9	0.325
Maltese	9 (20.0%)	10 (33.3%)	19	
Pomeranian	10 (22.2%)	6 (20.0%)	16	
Poodles	4 (8.9%)	7 (23.3%)	11	
Shih-Tzu	3 (6.7%)	2 (6.7%)	5	
Yorkshire Terrier	9 (20.0%)	3 (10.0%)	12	
Total	42	30	72	

*Fisher's exact test (*P* < 0.05).

ing order were the Maltese (n = 10), Poodle (n = 7), Pomeranians (n = 6), Yorkshire Terriers (n = 3), Chihuahuas (n = 2), and Shih-Tzu (n = 2). There was no significant difference in the breed distributions between sound and lame dogs (*P* > 0.05).

Sex

Of the 72 dogs, 26 were males (23 castrated), and 46 were females (26 spayed). Among all dogs, spayed females were most frequently observed (36%). Among sound dogs, 71.4% were female and 28.6% were male, whereas among lame dogs, 53.3% were female and 46.7% were male. Although there was no significant difference, the distribution of sound dogs among females was observed two times (OR = 2.188, *P* = 0.140). The ratio of lame to sound dogs among neutered animals was 1:1.2 and the ratio among intact animals was 1:1.9. The distributions of sound and lame dogs according to sex were shown in Table 2.

Age

The sound dogs had a mean age of 7.2 ± 4.0 years (mean ± standard deviation [SD]), and the lame dogs had a mean age of 5.1 ± 4.2 years. This indicated that sound dogs were older on average with statistical significance (*P* = 0.031). The mean ages of sound and lame dogs were compared according to each MPL grade (Table 3). Sound dogs showed a tendency toward older age as the MPL grade increased. There was no difference in the mean age between sound and lame dogs with MPL grades of 1, 2, or 4. In cases with MPL grade 3,

Table 2. Sex distribution between sound and lame dogs

Sex	Sound dogs	Lame dogs	Total	χ^2 (*P* value)*	OR†
	Number (%)	Number (%)			
Female	30 (41.7%)	16 (22.2%)	46	2.484	2.188
Male	12 (16.7%)	14 (19.4%)	26	(0.140)	
Intact	15 (20.8%)	8 (11.1%)	23	0.659	1.528
Neutered	27 (37.5%)	22 (30.6%)	49	(0.454)	
Intact female	13 (18.1%)	7 (9.7%)	20		
Spayed female	17 (23.6%)	9 (12.5%)	26	3.071	-
Intact male	2 (2.8%)	1 (1.4%)	3	(0.398)	
Castrated male	10 (13.9%)	13 (18.1%)	23		
Total	42	30	72		

*Chi-squared test (*P* < 0.05).
†Odds ratio.

Table 3. Age distribution associated with medial patellar luxation grade between sound and lame dogs

		Lame dogs	Sound dogs	*P* value*
		Mean ± SD (95% CI)	Mean ± SD (95% CI)	
MPL Grade	1	4.5 ± 2.1 (3.7-7.9)	5.9 ± 4.7 (3.6-8.3)	0.810
	2	4.3 ± 4.0 (1.6-7.0)	6.4 ± 4.3 (5.0-7.9)	0.119
	3	4.2 ± 3.2 (3.1-6.4)	7.4 ± 3.6 (6.1-8.7)	0.013
	4	9.8 ± 8.0 (3.4-18.1)	12.3 ± 0.9 (3.4-21.1)	0.564
Total		5.1 ± 4.2 (3.6-6.5)	7.2 ± 4.0 (6.0-7.5)	0.031

*Mann-Whitney U test (*P* < 0.05).
MPL, medial patellar luxation; SD, standard deviation; 95% CI, 95% confidence interval.

Table 4. Occurrence trend of sound and lame dogs according to age

Age	Sound dogs	Lame dogs	OR†	*P* value*	95% CI
	Number	Number			
≤ 1 year	4	8	1 Reference		
1 < years ≤ 7	16	13	3.0	0.262	0.4-16.4
7 < years ≤ 13	21	7	12.5	0.021	1.4-33.6
> 13 years	1	2	-	-	-

†Odds ratio.
*Logistic regression analysis (*P* < 0.05).
95% CI, 95% confidence interval.

the mean age of sound dogs was significantly higher than that of lame dogs ($P = 0.013$).

The probability of soundness in dogs between the ages of 7 and 13 years was 12.5 times higher than the likelihood of those under 1 year of age in the logistic regression analysis ($P = 0.021$). Table 4 showed the OR values according to age group (≤ 1 year, 1 year to ≤ 7 years, 7 years to ≤ 13 years, and > 13 years).

Body weight

Body weight ranged from 1.7 to 7.0 kg with a mean of 3.5 kg. The body weight of sound dogs ranged from 1.75 kg to 6.5 kg with a mean of 3.4 ± 1.1 kg. In lame dogs, body weight ranged from 1.82 kg to 7 kg with a mean of 3.5 ± 1.1 kg. Each mean body weight classified by MPL grade was shown in Table 5; there is no significant difference in the comparison between sound and lame dogs ($P > 0.05$).

Body condition score

The total BCS ranged from 2/5 to 5/5. Among sound dogs, three dogs had a BCS of 2 (7.1%), 29 dogs had a BCS of 3 (69%), and 10 dogs had a BCS of 4 (23.9%). A similar BCS distribution was observed among lame dogs as follows: one dog had a BCS of 2 (3.3%), 18 dogs had a BCS of 3 (60%), 10 dogs had a BCS of 4 (33.3%), and one dog had a BCS of 5 (3.3%). In an attempt to adjust the number of dogs accord-

Table 5. Body weight (kg) distribution between sound and lame dogs according to medial patellar luxation grade

		Sound dogs	Lame dogs	*P* value*
		Mean ± SD (95% CI)	Mean ± SD (95% CI)	
MPL Grade	1	3.8 ± 1.1 (3.2-4.3)	3.7 ± 0.6 (1.6-9.1)	0.589
	2	3.4 ± 1.4 (2.9-3.9)	2.9 ± 0.6 (2.5-3.3)	0.428
	3	3.3 ± 0.9 (3.0-3.6)	3.8 ± 1.2 (3.2-4.5)	0.125
	4	4.8 ± 1.2 (1.3-7.1)	3.3 ± 1.4 (1.1-6.9)	0.248
Total		3.4 ± 1.1 (3.0-3.8)	3.5 ± 1.1 (3.1-3.9)	0.753

*Mann-Whitney U test ($P < 0.05$).
MPL, medial patellar luxation; SD, standard deviation; 95% CI, 95% confidence interval.

Table 6. Body condition score distribution between sound and lame dogs

BCS	Sound dogs	Lame dogs	Total	χ^2 (*P* value)*	OR†
	Number (%)	Number (%)			
2	3 (4.2%)	1 (1.4%)	4	2.648 (0.496)	-
3	29 (40.3%)	18 (25.0%)	47		
4	10 (13.9%)	10 (13.9%)	20		
5	0 (0.0%)	1 (1.4%)	1		
≤ 3	32 (44.4%)	19 (26.4%)	51	1.474 (0.296)	1.831
> 3	10 (13.9%)	11 (15.3%)	21		
Total	42	30	72		

*Chi-squared test ($P < 0.05$).
†Odds ratio.
BCS, body condition score.

Table 7. Medial patellar luxation grade in sound and lame dogs

MPL grade	Sound limbs	Lame limbs	Total	χ^2 (*P* value)*	OR†
	Number (%)	Number (%)			
1	11 (15.9%)	2 (6.1%)	13	7.087 (0.171)	-
2	30 (43.5%)	11 (33.3%)	43		
3	26 (37.7%)	17 (51.5%)	43		
4	2 (2.9%)	3 (9.1%)	5		
≤ 2	41 (59.5%)	13 (39.4%)	54	4.891 (0.038)	2.253
> 2	28 (40.5%)	20 (60.6%)	48		
Total	69	33	102		

*Chi-squared test ($P < 0.05$).
†Odds ratio.
MPL, medial patellar luxation.

ing to BCS, they were divided into two groups: those with a BCS ≤ 3 and those with a BCS > 3. The distributions of BCS values were not different between sound and lame dogs ($P > 0.05$) (Table 6).

Grade of medial patellar luxation

Among the 72 dogs, a total of 102 limbs were evaluated and classified into two groups according to the presence or absence of lameness. Among the sound limbs, 11, 30, 26, and 2 limbs were grades 1, 2, 3, and 4, respectively. A similar MPL grade distribution was observed among lame dogs; 2, 11, 17, and 3 limbs were grades 1, 2, 3, and 4, respectively (Table 7). The limbs were divided into two groups: those with an MPL grade ≤ 2 and those with an MPL grade > 2. Sound limbs were about 2.2 times more frequent in the group with an MPL grade ≤ 2 when compared with the group with an MPL grade > 2 with statistical significance (OR = 2.253, $P = 0.038$).

Osteoarthritis score

The mean radiographic OA score of all limbs was 1.7 ± 2.0 and ranged from 0 to 12. The mean OA score was 1.6 ± 2.1 in sound limbs and 2.3 ± 2.0 in lame limbs. There was no significant difference between the sound and lame limbs ($P > 0.05$). Even after classification according to MPL grade, there was no statistical significance ($P > 0.05$) (Table 8).

Table 8. Osteoarthritis score compared between sound and lame dogs according to medial patellar luxation grade

		Sound limbs	Lame limbs	P value*
		Mean ± SD (95% CI)	Mean ± SD (95% CI)	
MPL Grade	1	1.3 ± 1.6 (0.5-2.1)	2.0 ± 0.0 (2.0-2.0)	0.319
	2	1.8 ± 2.0 (0.8-2.2)	1.8 ± 1.7 (0.6-3.0)	0.541
	3	1.6 ± 2.0 (0.8-2.3)	2.0 ± 1.9 (1.0-3.0)	0.342
	4	7.1 ± 4.9 (2.7-12.9)	6.6 ± 2.0 (0.5-13.8)	0.374
Total		1.6 ± 2.1 (1.2-2.1)	2.3 ± 2.0 (1.5-3.0)	0.063

*Mann-Whitney U test ($P < 0.05$).
MPL, medial patellar luxation; SD, standard deviation; 95% CI, 95% confidence interval.

Table 9. Measurement of anatomic lateral distal femoral angle compared between sound and lame dogs according to medial patellar luxation grade

		Sound limbs	Lame limbs	P value*
		Mean ± SD (95% CI)	Mean ± SD (95% CI)	
MPL Grade	1	99.5 ± 5.4 (97.3-102.5)	99.6 ± 9.3 (86.7-126.5)	0.401
	2	100.4 ± 6.4 (98.2-102.6)	102.6 ± 7.5 (97.6-107.7)	0.436
	3	105.6 ± 4.1 (104.1-107.1)	108.9 ± 5.9 (104.8-110.9)	0.048
	4	107.7 ± 3.0 (80.4-135.0)	111.5 ± 2.2 (105.9-117.0)	0.083
Total		102.3 ± 6.0 (101.0-103.6)	105.8 ± 7.0 (103.3-108.3)	0.001
Normal reference values		94.5 ± 2.9 (93.7-95.2)†		

*Mann-Whitney U test ($P < 0.05$).
†Kim *et al*. (2016).
MPL, medial patellar luxation; SD, standard deviation; 95% CI, 95% confidence interval.

Table 10. Measurement of inclination of femoral head angle compared between sound and lame dogs according to medial patellar luxation grade

		Sound limbs	Lame limbs	P value*
		Mean ± SD (95% CI)	Mean ± SD (95% CI)	
MPL Grade	1	129.6 ± 5.1 (127.1-132.1)	128.7 ± 4.8 (85.4-171.9)	0.905
	2	132.4 ± 5.2 (130.6-134.1)	131.3 ± 5.4 (127.7-135.0)	0.443
	3	132.0 ± 5.2 (130.1-133.9)	135.4 ± 6.2 (132.2-138.6)	0.054
	4	135.5 ± 4.9 (91.0-179.9)	135.5 ± 7.3 (117.2-153.7)	0.564
Total		132.1 ± 5.3 (131.0-133.2)	133.7 ± 6.1 (133.5-135.8)	0.190
Normal reference values		129.4 ± 3.8 (128.4-130.4)†		

*Mann-Whitney U test ($P < 0.05$).
†Kim *et al*. (2016).
MPL, medial patellar luxation; SD, standard deviation; 95% CI, 95% confidence interval.

Table 11. Measurement of mechanical medial proximal tibial angle compared between sound and lame dogs according to medial patellar luxation grade

		Sound limbs	Lame limbs	P value*
		Mean ± SD (95% CI)	Mean ± SD (95% CI)	
MPL Grade	1	97.4 ± 4.7 (95.1-99.7)	98.3 ± 1.9 (81.1-115.5)	0.549
	2	97.3 ± 5.4 (95.4-99.1)	97.5 ± 5.2 (94.0-101.0)	0.579
	3	98.0 ± 3.7 (96.6-102.7)	99.7 ± 5.9 (96.6-102.7)	0.776
	4	N/E	N/E	
Total		97.6 ± 4.6 (96.8-98.6)	98.8 ± 5.4 (96.7-100.8)	0.145
Normal reference values		97.6 ± 3.3 (96.8-98.5) †		

*Mann-Whitney U test ($P < 0.05$).
†Kim *et al*. (2016).
MPL, medial patellar luxation; SD, standard deviation; 95% CI, 95% confidence interval.

Measurement of pelvic limb alignment

From the 102 limbs of all dogs, differences were analyzed between the mean angles and SDs of the 69 sound limbs and 33 lame limbs. In addition, statistical processing of the mean angle was performed according to the severity of the MPL; the normal ranges of angles in small-breed dogs were shown in Tables 9, 10, and 11.

The mean aLDFA of sound limbs was 102.3 ± 6.0 degrees and significantly smaller than the mean aLDFA of lame limbs of 105.8 ± 7.0 degrees ($P = 0.001$). Overall, sound limbs tended to have a smaller mean value but statistical significance was observed only for grade 3 MPL ($P = 0.048$) (Table 9). The mean IFA of sound limbs was 132.1 ± 5.3 degrees and the mean mMPTA was 97.6 ± 4.6 degrees. The mean mMPTA and IFA were not statistically different between sound and lame limbs ($P > 0.05$). In addition, the mean mMPTA and IFA were not significantly different among the MPL grades ($P > 0.05$) (Tables 10, 11).

Discussion

MPL is a common orthopedic disorder in dogs and a leading cause of hindlimb lameness, pain, and degenerative change in the canine stifle joint. However, there are many asymptomatic dogs with MPL (1,13,14,17).

In this study, among the sound dogs, the Maltese, Pomeranian, Yorkshire Terrier, and Chihuahua breeds were overrepresented. The breed distribution was similar to those in other reports such as Poodles, Yorkshire Terriers, Pomeranians, and Chihuahuas (1,3,14). Unlike in previous studies, in this study, a high proportion of Maltese presented MPL; this seems to be related to the current preferences of the owners that visit VMTH-KU.

In the distribution of sound dogs with MPL, spayed females were most frequent. Recent studies reported a higher incidence of MPL in spayed females (1,5,11,13-15,25). They explained that hormones or genetic factors might be related to the incidence of MPL (1,3). Interestingly, the rate of sound dogs within the intact population was higher than that in the neutered population. In this study, the frequencies of sound dogs were high among female and intact dogs. Since the number of retrospective studies about the sex distribution of sound and lame dogs is low, there is a need to gather data from various sources.

While sound dogs with MPL were distributed across all ages, lame dogs with MPL were usually young. According to other reports, the age at MPL diagnosis with lameness was approximately 3 years or younger (1,5,9,14,26). A potential explanation for this finding is improved bone quality in mature animals (29). In skeletally immature dogs with MPL, abnormal pressure on the distal femoral physis may cause a more angular deformity (17,31). In addition, immature dogs have a larger potential for soft tissue deformation than do adult dogs (8). Therefore, when MPL is severe in young dogs, it is easy to induce abnormal joint movement.

Body weight was not different between the two groups in this study. According to a previous study, in dogs under 12 kg, body weight may not have a substantial influence on hind limb function (28). When comparing dogs according to BCS, the distributions of sound and lame dogs were similar. In another study, BCS was associated with the OA score and postoperative lameness after MPL reduction surgery (4). However, in this study, there was no statistical difference in BCS between sound and lame dogs.

MPL grades 2 and 3 were most frequently observed in both sound and lame dogs. A comparatively lower number of dogs with MPL grade 4 was observed; this was because of the limitation of relying on medical records in this retrospective study. In a study on prevalence conducted at three different centers, it is possible that the cases referred to the hospital did not accurately represent the overall population (3). In a study on prevalence at three different centers, it was possible that referral hospital cases did not accurately represent the overall population (3). In this study, to compensate for the small number of samples, the dogs were divided into two groups (theses with scores < 2); dogs with low-grade MPL tended to be sound rather than lame. This may be due to absent or mild bony deformities in low-grade MPL. Therefore, MPL grade 1 is commonly an incidental finding on routine physical examination and usually not associated with lameness (31). In cases of MPL grade 2, spontaneous luxation occurs with clinical signs of a non-painful, skipping type of lameness that then returns to normal ambulation (13,31). As such, this represents mechanical lameness and the clinical signs that may be observed vary depending on the degree of patient adaptation. Further studies will be necessary to identify changes in symptoms among sound dogs with untreated MPL grades 1 and 2.

Secondary OA is associated with a number of pathologic conditions including MPL (10,28). However, in this study, the OA score was not different between sound and lame dogs. Osteoarthritic changes in the joint may be somewhat lesser importance since degenerative changes develop slowly (13). Therefore, OA may provide evidence of pathology, but it is not representative of limb function (12,16,28). In another opinion, OA did not necessarily induce lameness. In a previous study conducted on OA in dogs with MPL, the lameness grade did not influence OA scores (28). Further, it has been estimated that 20% of healthy adult dogs have OA (21).

Most dogs with MPL have associated musculoskeletal abnormalities. Anatomic and mechanical factors affecting loading in the stifle joint should be considered in diagnosis and treatment because they can contribute to pathologic changes (2,7,23,32). For this purpose, standardized measurements of lower limb alignment and joint orientation that are performed in human medicine have recently been described in large- and small-breed dogs (17,32). Kim *et al*. provided reference values for femoral and tibial joint angles in small-breed dogs (17).

The femoral varus angle was defined in relation to the aLDFA (aLDFA - 90°). In this study, aLDFA values were measured in the groups with sound and lame limbs according to MPL grade. As the MPL grade increased, the mean aLDFA tended to increase in both sound and lame limbs, which is in agreement with previous reports (32,33). However, there was a difference in the degree of deformity between sound and lame limbs, and the femoral varus deformity was generally less severe in sound limbs. In particular, the differences were evident in MPL grade 3. In this study, the two dogs with MPL grade 4 were sound despite moderate-to-severe femoral varus. As was also shown in another report, some dogs with MPL have good clinical function despite severe anatomical abnormalities (11). Based on these results, it is presumed that in some sound dogs with radiological abnormalities, the abnormalities seem to be functionally tolerable.

Changes in the IFA cause coxa vara or coxa valga. In the past, there was a hypothesis regarding a relationship between MPL and coxa vara (15,27). However, recent studies in small-breed dogs suggest that coxa valga is considered as a greater risk factor for MPL (3,14). The reported normal ranges from radiographs were 129.4 ± 3.8 degrees (17) and 127.7 ± 6.3 degrees (33). In this study, the values were found to be at the upper limit of or slightly greater than normal reference values. Thus, most limbs were found to have coxa valga. However, there was no difference between sound and lame dogs.

Proximal tibia varus deformity was determined by the mMPTA; it is easily measured in the frontal plane and used as an indicator for osteotomy (6,9,19,24). Conversely, not all measurement values of the tibia could be evaluated in the MPL grade 4 group because of severe internal rotation of the tibia. In this study, the mean mMPTA showed no difference between sound and lame dogs for any MPL grade. Because the stifle joints do not fully straighten in MPL grades 3 and 4, it may be difficult to attain a correct posture (31). In addition, measuring morphometric techniques using radiographs is technically difficult (6,9,33). Improper postures or landmark placements may result in substantial error (6,17). A variation of more than 2-3 degrees between radiographs suggests a positioning or measurement artifact (30,31). These factors should always be considered when evaluating radiography in small-breed dogs.

There are some limitations to this study. Even though a widely used scoring system was utilized, tools that are more objective are available to evaluate lameness such as force platform gait analysis (12,21). Additionally, in this study, the description of the bone deformity measurement was limited primarily to radiography. Femoral anteversion and tibial rotation also have been implicated in the pathogenesis of MPL (14,22,33). The study focused on the frontal plane alone and therefore did not address femoral anteversion or other tibial deformities. Another limitation is related to the study's retrospective nature. It is possible that there are other clinical factors associated with sound dogs such as the degree of muscle atrophy, muscle tone, and soft tissue abnormalities.

Conclusion

Clinical factors such as breed, sex, body weight, BCS, OA score, mMPTA, and IFA were not associated with the incidence of sound dogs with MPL. In cases with MPL grades 1 and 2, the frequency of sound dogs was significantly higher than in cases with MPL grades 3 and 4. In MPL grade 3 cases, if the dogs were 7.4 ± 3.6 years old and their aLDFA was 105.6 ± 4.1, the dogs seemed to be sound. This study can help provide information about the clinical features of sound dogs with MPL.

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