Degrees of Tibial Plateau Angle and its Relation With dogs' Weight and Age in the Cases of Cranial Cruciate Ligament Rupture in Dogs: an Analysis of 90 Cases

Samanta Užanskytė[1], Karolis Vainalavičius[1]
[1]*Veterinary clinic "Kaivana", Kaunas, Lithuania*

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Abstract*. Tibial plateau angle (TPA) is important for treatment selection of cranial cruciate ligament (CCL) rupture. The aim of this study was to determine the highest deviation of the TPA from normal range and to find the relation between the TPA degree, patients weight and age that show TPA influence in degeneration of the stifle joint and CCL rupture. The hypothesis of this research analysis was that dogs with CCL rupture have a significantly greater TPA than normal ranges. Ninety radiographs of dogs with CCL rupture were analyzed and the TPA was measured. All dogs examined were divided into four groups according to weight categories and each of these groups was divided into three subgroups according to age. In each weight and age group, the minimum and maximum degrees of the TPA and dogs ages and their mean were determined for all dogs in the group. The differences of largest and smallest deviations and means between weight groups were not statistically significant, as $P > 0.05$. However, all dogs with CCL rupture had a higher TPA than it is recommended ($P < 0.05$). The average TPA of all groups was 25.8 degrees and the highest TPA was 34 degrees. According to the results of the age groups, it was determined that there were no dogs younger than 1.5 years old in small and medium breed groups that had CCL rupture; most of them were in the geriatric age, which means that most of CCL rupture cases were because of the degeneration of CCL that might be caused by a high TPA degree. On the contrary, the majority of large and giant breed dogs that had CCL rupture were in the young and middle age. The differences of ages of groups were statistically significant, as P was <0.05. In conclusion, because the TPA average of all tested dogs was more than 10 degrees higher than recommended safe normal ranges, it should be kept in mind and treatment has to be aimed to reduce the strain in the stifle joint.*

Introduction

The cranial cruciate ligament (CCL) is a very important stabilizer inside the canine stifle joint. Rupture of the CCL is one of the most common stifle pathologies in dogs, especially in large breeds (Tobias and Johnston, 2013). In small breed dogs, CCL rupture is the second pathology after patellar luxation (Dona et al., 2016). CCL rupture is caused by many factors, such as genetics, overweight, bone deformities (genu varum, genu valgum, tibial or femoral torsion or both), patellar luxation, and excessively sloped proximal tibial plateau (Calvo et al., 2020). It is observed that some dog breeds are more susceptible than others, and its reason could be the degree of the tibial plateau angle (TPA) because it is different in all breeds of the dogs (Nečas et al., 2000). The research conducted in 2021 analyzed correlation between the TPA and dogs' weight, but it was found not statistically significant (Sörensson, 2021). One of the main causes of rupture of the CCL is an abnormally increased angle of the TPA. The reason for the large TPA is the deformities that occur during the growth of the proximal tibia (Reif and Probst, 2003). In their research, Read and Robins found that the TPA was highly increased in 4 of 5 dogs that experienced rupture of the CCL (Read and Robins, 1982). At a high degree of the TPA, the CCL is subjected to a much higher strain than in dogs with a degree of TPA within the normal range (Morris and Lipowitz, 2001). Although there is no specific one degree corresponding to the normal TPA, the recommended range of norms for the postoperative stability of the stifle joint is an angle of 4 to 6 degrees (Calvo et al., 2020). Dogs with a TPA up to 15 degrees are also thought to have a lower risk of CCL rupture than dogs with a higher TPA (Conkling et al., 2009). The rupture of this ligament can be partial or complete. In older dogs, the etiology of CCL rupture is often of degenerative origin (Ichinohe et al., 2015). The majority of ligament rupture cases are associated with synovial inflammation or degenerative lesions of the ligament cells and the tissue itself (Hayashi et al., 2004). The ligament is initially only partially damaged by rupture of the ligament fibers, and later, if the disease progresses and treatment is not started in time, a complete rupture of the ligament occurs. In young dogs the cause of CCL rupture is most often of a traumatic origin, in which case the rupture is usually complete because traumatic avulsion is present (Ichinohe et al., 2015).

In chronic processes of CCL injury, pain, decreased range of motion, muscle atrophy, swelling,

Correspondence to Samanta Užanskytė, Veterinary clinic "Kaivana", Veiverių g. 71, LT – 46355, Kaunas, Lithuania.
E-mail: samanta.uzanskyte@gmail.com

abnormal posture when standing, getting up, lying down or sitting, abnormal gait when walking, trotting, climbing stairs or turning, grating or grinding joint movement, and nervous system signs like confusion and trembling are often recorded in a clinical examination (Harasen, 2002). The aim of this study was to determine the highest deviation of the TPA from normal ranges and to find the relation between the TPA degree, patients weight and age that show TPA influence in degeneration of the stifle joint and CCL rupture. The hypothesis of this research analysis was that dogs with CCL rupture have a significantly greater TPA than normal ranges.

Materials and methods

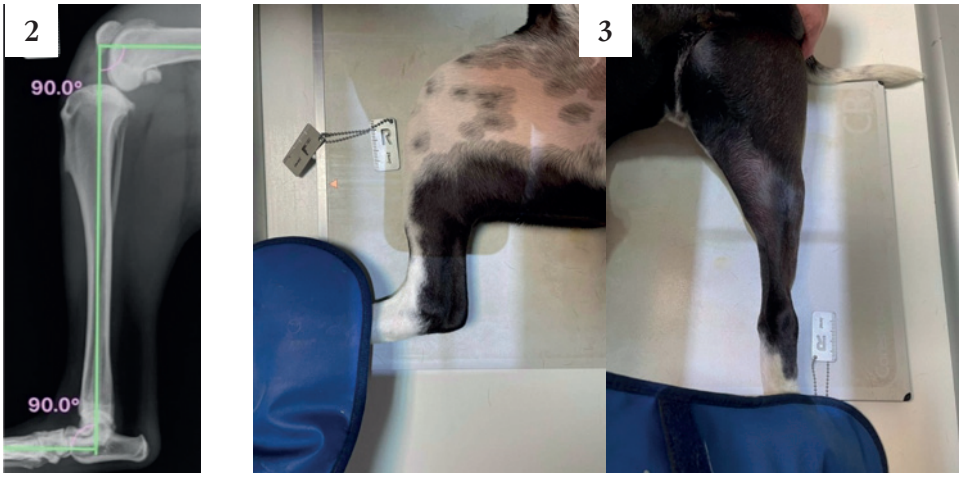
Ninety dogs that had lameness in the hind leg were taken for the research. There was no age or weight limit. All these dogs were tested in 2018–2021, and the examinations were performed at the veterinary clinic "Kaivana". During the examination, the majority of the affected legs had edema, soreness, a positive "drawer movement" test, and/or a positive tibial compression test (Fig. 1).

All of these dogs were sedated with dexmedetomidine hydrochloride and butorphanol medications. A dexmedetomidine hydrochloride dose of 300 μg/m^2 was counted following producer's recommendations and 0,01 mL/kg butorphanol was given following producer's guidelines. Radiographies were made on the affected legs under mediolateral (ML) and caudocranial (CC) projections prior to surgical treatment (tibial plateau leveling osteotomy). X-ray examination was performed with a Toshiba D045 X-ray machine, and imaging was performed using the CARESTREAM Vita Flex CR system. During the positioning of the ML projection, the leg at the stifle joint was flexed at an angle of 90 degrees, and during the CC projection, the leg at the stifle joint was considered to be extended and centered via distal tibia (Figs. 2, 3).

X-rays were performed to measure the TPA. In order to measure the TPA, two main axes were drawn: the axis of the tibial plateau passing through the cranial and caudal edge of the joint surface, and the longitudinal (functional) tibial axis line passing through the center of the tibial intercondylar eminence and the center of rotation of the talus. Through the point of intersection of these axes, an additional line was drawn perpendicular to the longitudinal axis, and the degree of angle between the axis of the tibial plateau and the additional line was calculated (Fig. 4) (Calvo et al., 2020).

All dogs examined were divided into four groups according to weight categories: group 1 – small (up

Fig. 1. A positive tibial compression test in a dog.



Figs. 2, 3. A dog positioned for ML and CC radiographs of the hind leg.

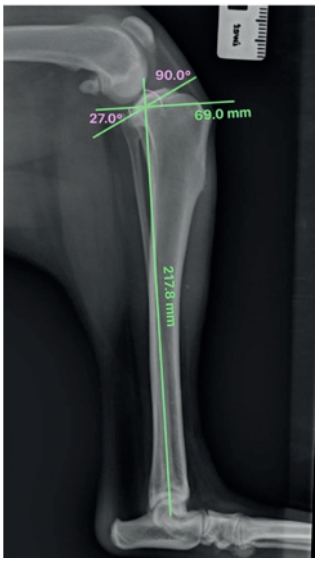


Fig. 4. Measurement of the tibial plateau angle in a dog.

to 10 kg); group 2 – medium (10.1–20 kg); group 3 – large (20.1–40 kg); and group 4 – giant (over 40 kg). Each of these groups was divided into three subgroups according to age: group 1 – young (up to 1.5 years); group 2 – middle (1.6–6 years); and group 3 – geriatric (over 6 years). In each weight group, the minimum and maximum degrees of the TPA and the mean with a deviation of the group degrees were determined for all dogs in the group. In each age group, the minimum and maximum ages were identified, and the mean with deviation of the groups of ages were determined for all dogs in the group.

Statistical analysis

Statistical data were processed using Microsoft Excel2018: arithmetic means with deviation (SD), maximum and minimum indicators were calculated. Data were considered reliable when the P value was less than 0.05.

Results

Group 1 (small dogs up to 10 kg)

The lowest degree of the TPA in the group was 23, the maximum was 31, and the mean (± SD) of the TPA in all dogs in the group was 28.2 ± 2.1 degrees (Table 1).

Group 2 (medium dogs of 10.1–20 kg)

The lowest degree of the TPA in the group was 22.5, the maximum was 32, and the mean (± SD) of the TPA in all dogs in the group was 26.9 ± 3.2 degrees (Table 2).

Group 3 (large dogs of 20.1–40kg)

The lowest degree of the TPA in the group was 18, the maximum was 34, and the mean (± SD) of the TPA in all dogs in the group was 24.2 ± 3.9 degrees (Table 3).

Group 4 (giant dogs of over 40 kg)

The lowest degree of the TPA in the group was 19, the maximum was 31, and the mean (± SD) of the TPA in all dogs in the group was 24.0 ± 3.5 degrees (Table 4).

The highest average of the TPA (28.2) was in the first group of weight and the lowest average of the TPA (24.0) was in the fourth group (Fig. 5).

In the first group of weight, the majority of the dogs were older than 6 years old and belonged to the

Table 1. Weights of the first group of dogs

Dogs of the first group of weight	Weight of the dog (kg)	TPA degrees
1	10	29.8
2	10	29
3	5	27.3
4	8	29.9
5	4	23
6	8.2	29.9
7	6	28
8	4.6	26
9	10	29
10	6.5	30
11	5	27
12	9.9	31
13	8	25
14	5.1	28.5
15	2.2	27.4
16	8.2	31
17	10	29
18	10	26
19	9.8	29
20	6	29

Table 2. Weights of the second group of dogs

Dogs of the second group of weight	Weight of the dog (kg)	TPA degrees
1	16	23
2	16.5	22.5
3	20	28.1
4	15	27.5
5	11	28
6	12.6	30
7	20.4	32
8	16.1	29
9	20	24
10	15.9	30
11	11	23
12	14.3	26

third group of age (15 cases), fewer dogs (5 cases) belonged to the second group of age (middle aged dogs) and there were no dogs younger than 1.5 years old (Fig. 6).

Table 3. Weights of the third group of dogs

Dogs of the third group of weight	Weight of the dog (kg)	TPA degrees
1	22	25
2	30.3	21
3	40	20.6
4	37.5	24.2
5	36	21
6	22	20.5
7	40	27
8	35.1	24
9	30	19.8
10	35	25.2
11	35.9	28
12	40	24
13	30.6	25
14	21	28
15	30	25
16	35.2	28
17	40	24
18	35	34
19	30	18
20	35.7	20
21	35	24
22	40	20
23	35.5	29
24	35.1	25
25	35	27.3
26	35	22
27	35.6	33
28	40	24
29	25.8	22
30	35	25
31	25.6	29
32	40	23
33	26.5	31
34	25	23
35	30.3	18
36	35	25
37	25.2	19
38	40	20
39	35.7	25

Table 4. Weights of the fourth group of dogs

Dogs of the fourth group of weight	Weight of the dog (kg)	TPA degrees
1	45	26
2	60.7	19.8
3	80	24
4	50	27
5	50.4	24
6	44	23
7	90.3	22
8	50	31
9	80.4	23
10	60.5	23
11	60	29
12	50.5	22
13	60.9	22
14	60	25
15	45	20
16	45.6	30
17	46	19
18	55	20
19	45.3	26

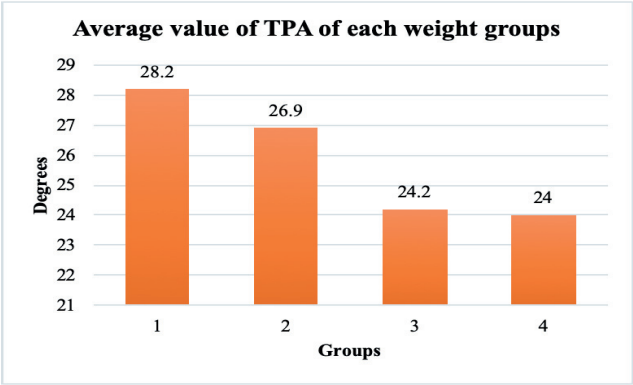


Fig. 5. Average value of the TPA of each weight group.

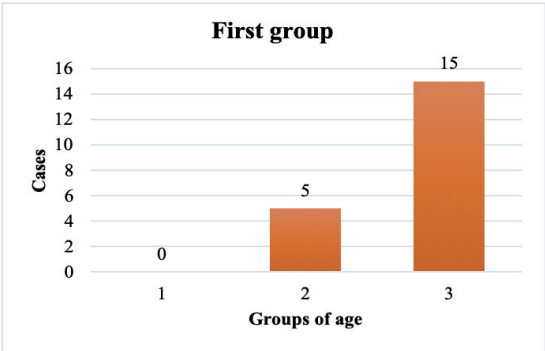


Fig. 6. The first group of weight and subgroups of age.

In the second group of weight, the majority of the dogs were older than 6 years old and belonged to the third group of age (9 cases), fewer dogs (3 cases) belonged to the second group of age (middle aged dogs) and there were no dogs younger than 1.5 years old (Fig. 7).

In the third group of weight, the majority of the dogs were 1.6–6 years old dogs and belonged to the second group of age (22 cases), fewer dogs (15 cases) belonged to the third group of age (geriatric dogs), and there were 2 dogs younger than 1.5 years old (Fig. 8).

In the fourth group of weight, the majority of the dogs were 1.6–6 years old dogs and belonged to the second group of age (12 cases), fewer dogs (4 cases) belonged to the third group of age (geriatric dogs), and there were 3 dogs younger than 1.5 years old (Fig. 9).

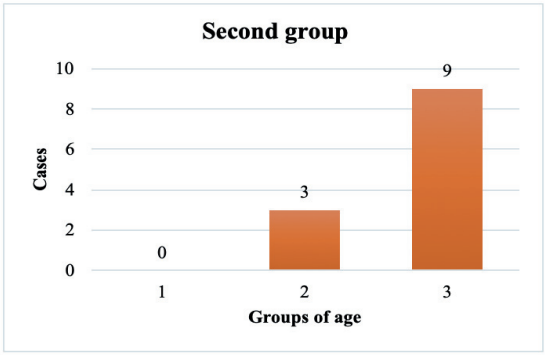


Fig. 7. The second group of weight and subgroups of age.

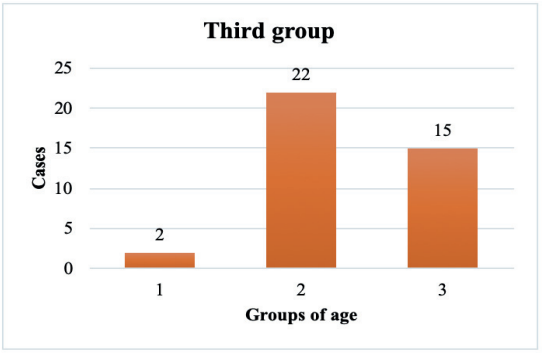


Fig. 8. The third group of weight and subgroups of age.

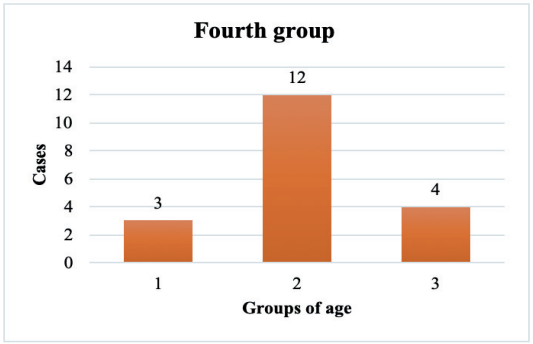


Fig. 9. The fourth group of weight and subgroups of age.

The maximum and minimum deviations from the degree of the TPA were found in the third group (large 20–40 kg) in all study dogs, and the mean (± SD) TPA in all study groups was 25.8 ± 2.1 degrees. The differences of the largest and smallest deviations and means between the groups were not statistically significant, as $P > 0.05$. However, all tested dogs had a higher TPA than it is recommended ($P < 0.05$). The highest average TPA (28.2) was in the first group of weight and the lowest average TPA (24.0) was in the fourth group of weight; however, the differences between the average TPA of these groups was not statistically significant, as P was > 0.05.

The youngest dog in the first group of age was 4 years old and the oldest dog was 13 years old. The average (± SD) of age in all dogs in the group was 8.2 ± 2.5 years. The youngest dog in the second group of age was 5 years old and the oldest dog was 13 years old. The average (± SD) of age in all dogs in the group was 7.7 ± 2.3 years. The youngest dog in the third group of age was 1 years old and the oldest dog was 11 years old. The average (± SD) of age in all dogs in the group was 5.4 ± 2.9 years. The youngest dog in the fourth group of age was 1 years old and the oldest dog was 8 years old. The average (± SD) of age in all dogs in the group was 4 ± 2.3 years. According to the results of the age groups, it was determined that there were no dogs younger than 1.5 years old in small and medium breed groups that had CCL rupture; however, most of them were in the geriatric age. On the contrary, the majority of large and giant breed dogs that had CCL rupture were in the young and middle age groups. The differences of ages between the groups were statistically significant, as P was <0.05.

Discussion and conclusion

The function of the CLL of the stifle joint is to provide stability in any phase of movement of the knee joint, preventing the tibia from sliding cranially to the femur, and to help prevent excessive rotation inside or outside (*varus et valgus*) during flexing of the stifle joint (Fossum, 2013). In the research by Reif and Probst in 2003, there was no statistical significance found between the TPA in healthy dogs and in dogs with CCL rupture (Reif and Probst, 2003). Nevertheless, the research of Arruda et al. shows that the TPA can possibly influence the etiology of CCL rupture in dogs (Flavia et al., 2018). This finding is in agreement with our study: the TPA of all study dogs with a CCL rupture was significantly higher than the recommended "safe" norm. However, there was no significant difference between the TPA index in the groups of dogs' weight. According to our study, it could be stated that the TPA is a very important factor in terms of CCL rupture, since the higher the degree of the TPA, the greater the strain on the ligament to maintain joint stability. Even though the TPA is a very important aspect in CCL rupture

cases this does not yet prove that this alone affects CCL rupture (Reif and Probst, 2003). As Brinker, Piermattei and Flo's state, CCL rupture may also be caused by femoral or tibial torsion, dog weight, stifle degenerative processes, or systemic inflammatory joint diseases such as rheumatoid arthritis (Brinker et al., 2016). Our study is in agreement with this theory because the largest average of the TPA was found in the small breed group and the majority of CCL cases in small breeds were dogs in the geriatric age (Fig. 10). It means that most of CCL rupture cases were because of the degeneration of CCL (that was seen during surgery: excessive synovial fluids, osteophytes, cartilage lesions, etc.) that might be caused by the high TPA degree. On the other hand, there were cases that CCL ruptured in young age dogs and the TPA was low enough (trauma being the reason), which proves that not only the TPA has influence on CCL rupture; however, the cases like that were quite rare in our study.

Because the TPA is thought to play a significant role in CCL rupture, it is important to consider this when choosing the right treatment option. Nowadays, intracapsular or extracapsular reconstruction is becoming less and less common, especially for large breed dogs. Its goal is to restore the passive restraining forces of the stifle joint, but even an implanted

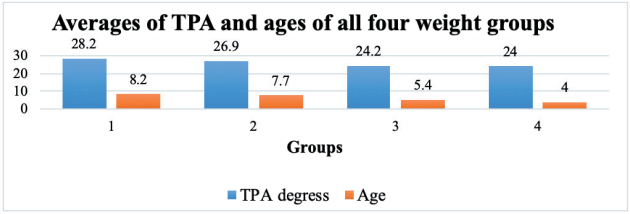


Fig. 10. Averages of the TPA and ages of all four weight groups

artificial ligament with a high degree TPA can rupture over time in the same way as the natural CCL. More successful treatments are tibial plateau leveling osteotomy (TPLO) and tibial tuberosity advancement (TTA) (Lazar et al., 2005). The purpose of the TPLO is to change the mechanics of the stifle joint by actively restraining it to achieve its stability. During osteotomy, the slope of the tibial plane is changed so that it and the patella would be perpendicular to each other. Since cranial tibial instability is proportional to the slope of the tibial plane, a decreasing slope also reduces cranial tibial instability. The TTA aims to eliminate tibial instability by moving the patellar tendon perpendicular to the sliding force in the knee joint. However, tibial fracture, implant rejection, meniscus damage, and other complications are possible after TTA (Boudrieau, 2009).

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