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Complications and the quality of life after surgical correction of medial patellar luxation in dogs

Komplikationer och livskvalitet efter kirurgisk behandling av medial patellaluxation hos hund

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SUMMARY

Medial patellar luxation is one of the most common orthopedic disorders in dogs, especially in small breed dogs. It is, in most cases, a developmental disorder associated with skeletal deformities and malalignment of the extensor mechanism. Patellar luxation is classified into four grades, see Table 2. Surgical treatment is composed of bone reconstructive techniques and soft tissue reconstructive techniques and is often performed in dogs with patellar luxation grade 2-4. The most common complications after surgery are patellar reluxation and implant related complications, according to previous studies. In many studies, an increased risk of complications has been associated with the severity of the luxation. In most previous studies assessing the outcome of surgery, the objective has been the short-term outcome. Owner questionnaires that evaluate surgical outcome, compare treatment methods, assess chronic pain, function and quality of life has recently been used in several studies with dogs affected by orthopedic diseases.

The purpose of this thesis is to evaluate complications, the long-term outcome and the quality of life in dogs treated surgically for medial patellar luxation. The purpose is also to analyze if there exist any factors that affect the complication rate and the long-term quality of life. Retrospective data such as patellar grade, surgical methods, complications, and bilateral or unilateral disease, have been recorded from the medical records of 45 dogs treated surgically for medial patellar luxation at the University Animal Hospital in Uppsala year 2012-2015. In this study, owners of the surgically treated dogs answered an online questionnaire regarding their dog's stiffness, function, lameness, and quality of life in October-November 2017. The answers were converted into a score. To assess the quality of life in the surgically treated dogs, the answers and the total scoring of the questionnaire has been compared with the answers of a control group composed of dogs without any orthopaedic disease.

The total postoperative complication frequency within one year was 31.7% among the cases with available medical data (41 out of 49 cases). Gastrointestinal symptoms were the most common complication. All dog owners in the case group who answered the questionnaire (29 out of 45) except one rated their dog's comfort to be better today than before the surgery, but some dogs still experience discomfort. Most of the surgically treated dogs had a good or acceptable score on the questionnaire, but there was a significant difference in scoring between the case group and the control group. This finding indicates that even after a successful surgical correction of medial patellar luxation, the expectation cannot be to regain equal mobility and function in the stifle joint compared to a dog without any orthopedic disorder. There was a great variation in total scoring among the surgically treated dogs, but the reason for this variation could not be concluded. Lameness was the most common problem for the surgically treated dogs according to the owners. Mobility and function were also affected but to a lower extent. The dogs' mood, willingness to participate in play, vocalization, and quality of life seems to be comparable between surgically treated dogs and dogs without any orthopedic disorder. Further research is needed to study the factors that could affect the long-term outcome, quality of life and lameness in surgically treated dogs.

SAMMANFATTNING

Medial patellaluxation är en av de vanligaste ortopediska sjukdomarna hos hund, speciellt bland små hundraser. I de allra flesta fall är medial patellaluxation en utvecklingssjukdom förknippad med skeletala missbildningar och en felaktig dragriktning av knäledens sträckarmuskulatur. Ett graderingssystem med fyra nivåer används för att klassa patellaluxation från lindrig till allvarlig, se Tabell 2. Kirurgisk behandling inkluderar rekonstruktion av skelett och mjukvävnad och utförs oftast på patienter med grad 2-4. Andra studier har visat att de vanligaste komplikationerna efter kirurgi är kvarstående patellaluxation och implantatrelaterade komplikationer. Många studier har visat på en ökad risk för komplikationer hos hundar med allvarlig patellaluxation. Flera studier har undersökt resultat efter kirurgi men fokus har oftast varit det kortsiktiga resultatet. På senare tid har frågeformulär som fylls i av djurägaren börjat användas mer inom forskningen för att utvärdera resultat, jämföra behandlingsmetoder, uppskatta kronisk smärta, funktion och livskvalitet hos hundar med ortopedisk sjukdom.

Syftet med detta arbete är att utvärdera komplikationer, långsiktigt resultat och livskvalitet hos hundar som opererats för medial patellaluxation. Syftet är också att analysera faktorer som kan påverka komplikationsfrekvensen samt livskvaliteten på lång sikt. Retrospektiv data så som luxationsgrad, kirurgiska metoder, komplikationer och bilateral eller unilateral sjukdom har sammanställts från patientjournaler tillhörande 45 hundar som opererats för medial patellaluxation på Universitetsdjursjukhuset i Uppsala år 2012-2015. Ägarna till dessa hundar har besvarat en enkät som behandlar ämnena stelhet, funktion, hälta och livskvalitet hos hundarna. Enkäten besvarades under oktober och november år 2017. Svaren har omvandlats till poäng. För att bedöma livskvaliteten hos de opererade hundarna har svaren och totalpoängen på enkäten jämförts med svaren från en kontrollgrupp bestående av hundar utan ortopedisk sjukdom.

Den sammanlagda komplikationsfrekvensen var 31,7 % bland de fall där medicinsk data kunde erhållas (41 av 49 fall). Gastrointestinala besvär var den vanligaste komplikationen. Alla opererade hundar utom en är mindre besvärade av sitt opererade ben nu än innan operationen enligt de djurägare som besvarade enkäten (29 av 45), men alla hundar är inte helt besvärsfria. Många av de opererade hundarna hade en bra eller någorlunda bra totalpoäng på enkäten men skillnaden i totalpoäng mellan de opererade hundarna och kontrollgruppen var signifikant. Detta indikerar att trots en korrekt utförd knäoperation så kan förväntningen inte vara att få lika bra mobilitet och funktion i knät som en hund utan ortopedisk sjukdom. Totalpoängen hos de opererade hundarna varierade i hög grad, men orsaken till variationen kunde inte klargöras. Hälta var det vanligaste problemet hos de opererade hundarna enligt ägarna. Rörlighet och funktion var också nedsatta men till en mindre grad. Hundarnas sinnesstämning, vilja att delta i lek, vokalisering och livskvalitet var likvärdiga mellan grupperna. Mer forskning behövs för att utvärdera vilka faktorer som kan påverka resultatet efter patellakirurgi, livskvalitet och hälta på lång sikt.

CONTENT

LIST OF ABBREVIATIONS

aLDFA	Anatomical lateral distal femoral angle
AOI	Angle of inclination
COI	Canine orthopedic index
CrCL	Cranial cruciate ligament rupture
FCI	Fédération Cynologique Internationale
FVA	Femoral varus angle
HCPI	Helsinki chronic pain index
LPL	Lateral patellar luxation
MDS	Multifactorial descriptive scale
MPL	Medial patellar luxation
NSAIDs	Nonsteroidal anti-inflammatory drugs
OFA	The Orthopedic Foundation for Animals
Q-angle	Quadriceps angle
SKK	The Swedish Kennel Club
SSI	Surgical site infection
TTT	Tibial tuberosity transposition
UDS	The University Animal Hospital

INTRODUCTION

Medial patellar luxation (MPL) is one of the most common orthopedic disorders in dogs (LaFond *et al*., 2002; Bosio *et al.*, 2017). MPL is more common in small breed dogs than in large breed dogs, but MPL is still more common than lateral patellar luxation (LPL) in all weight groups (Hayes *et al.*, 1994; Alam *et al.*, 2007; Bosio *et al*., 2017). Diagnosis of patellar luxation is based on gait evaluation and physical examination (Kowaleski *et al.*, 2012). Patellar luxation is classified into four grades where grade 1 is a mild luxation, and grade 4 is a severe luxation, see Table 2 (Singleton, 1969). Surgical treatment is often performed in dogs with MPL grade 2-4. The aim of surgical repair is to stabilize the patella within the trochlear groove and to realign the quadriceps mechanism. A combination of bone reconstructive techniques and soft-tissue reconstructive techniques are often performed (DeCamp *et al.,* 2016).

There are several factors that can affect the outcome and prognosis after surgery, where the luxation grade probably is the most important factor (Hans *et al.*, 2016). In several studies, patellar reluxation is the most common complication after surgery (Arthurs & Langley-Hobbs, 2006; Gallegos *et al.,* 2016; Bosio *et al.,* 2017). In the literature, the frequency of patellar reluxation has been reported to be 0-48% (Willauer & Vasseur, 1987; Roy *et.al.*, 1992; Arthurs & Langley-Hobbs 2006); Wangdee *et al.,* 2013; Cashmore *et al.,* 2014; Bosio *et al.,* 2017; Perry *et al.,* 2017). Most of the previous studies are focused on short-term post surgery outcome. Only a few studies have evaluated long-term outcome more than one year post surgery by follow-up examinations or interviews with the dog-owners (Willauer & Vasseur, 1987; Swiderski & Palmer, 2007; Brower *et al.*, 2017).

The aim of this thesis is to evaluate outcome after surgical correction of MPL in dogs, focusing on the long-term outcome. The thesis consists of two parts. The first part is a retrospective study where the medical records of dogs treated surgically for MPL at the University Animal Hospital (UDS) in Uppsala year 2012-2015 have been reviewed. The collected data include surgical methods, preoperative patellar grade, and complications after surgery, among other things. The second part of the thesis is a quality of life study where owners of the dogs in the retrospective study have answered a questionnaire regarding their dog's function, stiffness, gait, and quality of life.

The purpose with the two parts of the study was to analyse correlations between different variables, for example, preoperative patellar grade and complications, and the dogs' quality of life. The purpose was also to assess the quality of life in surgically treated dogs and to compare this to the quality of life in dogs without any orthopedic disorder. This analysis will provide a realistic view of what outcome to expect after surgery, and if a dog surgically treated for MPL can acquire equivalent function, mobility, and quality of life comparable to a dog without any orthopedic disorder.

LITERATURE REVIEW

Anatomy and physiology of the patella and the extensor mechanism

The patella is a sesamoid bone located in the tendon of the quadriceps muscle group (Hulse, 1993). The patella is a part of the extensor mechanism of the stifle joint, which is composed of the quadriceps muscle group, the patella, the trochlear groove of femur, the straight patellar ligament and the tibial tuberosity. The quadriceps muscle group is composed of the rectus femoris, which originates on the ventral aspect of the ilium cranial to the acetabulum, the vastus medialis, vastus lateralis, and vastus intermedius, which originates on the proximal femur (Liebich *et al.,* 2009). The quadriceps muscle group merges on the patella, continues as the patellar ligament and attaches to the tibial tuberosity located cranial and distal to the tibial condyles. The patella articulates with the stifle joint in the trochlear groove that is situated at the cranial surface of distal end of the femur between the medial and lateral trochlear ridges. Medial and lateral femoropatellar ligaments connect the patella to the femoral epicondyle medially and the fabella laterally (Evans & de Lahunta, 2013). The joint capsule, the femoral fascia and the femoropatellar ligaments stabilises the patella and the joint.

The function of the extensor mechanism is to extend the stifle joint and to assist in maintaining the stability of the stifle joint (Hulse, 1993). The patella acts as a lever arm when the quadriceps muscle group is contracted, increasing the mechanical force of the muscle and maintains an even tension when the stifle is extended. It also provides cranial and rotary stability to the stifle joint and protects the tendon. The articulation of the patella in the trochlear groove is necessary to provide proper nutrition to the articular cartilage (Hulse, 1981). During growth, the presence of the patella in the trochlear groove is necessary for the development of the groove (Kowaleski *et al.*, 2012). The shape, depth, and width of the trochlear groove develop under the pressure the patella exerts.

The proper anatomic alignment of the extensor mechanism is a straight line of force (Hulse, 1981). For the patella to be stable, the quadriceps muscle group, the femoral shaft, the patella, the trochlear groove, the patellar ligament, and the tibial tuberosity must align (Hulse 1981; 1993; Roush, 1993; Kowaleski *et al.*, 2012; DeCamp *et al*., 2016). The line representing the direction of force created by the quadriceps muscle and the axis of patellar ligament creates an angle called the quadriceps angle, or Q-angle, see Figure 1 (Kaiser *et al.*, 2001). The normal stifle joint of the dog has a Q-angle of 10 degrees medially.

Patellar luxation is thought to be multifactorial and may be related to the conformation of the entire pelvic limb (Hulse, 1993). Normal anatomy of the hip, the femur, and the tibia must be understood before discussing the pathophysiology. Different angles in the hip, the femur, the stifle and the tibia are discussed in the literature (Kowaleski *et al.*, 2012).

Femoral varus can be evaluated by measuring the femoral varus angle (FVA) or the anatomical lateral distal femoral angle (aLDFA) (Soparat *et al*., 2012). The FVA is the angle formed between the proximal femoral long axis and the distal femoral long axis at their intersection (Dudley *et al*., (2006). The aLDFA is the angle formed by the intersection of the anatomic axis and the joint reference line (Tomlinson *et al.*, 2007). The joint reference line is a line drawn from lateral to medial just below the condyles. The aLDFA is illustrated in Figure 1. Soparat *et al.* (2012) showed a normal mean FVA of 5.85 degrees and aLDFA of 95.21 degrees for Pomeranians. These numbers are similar to those reported by Olimpo *et al*., (2016) who found the mean aLDFA to be 95.3 in small breed dogs <7.5 kg. Tomlinson *et al.*, (2007) found the mean aLDFA to be 97 degrees in Labrador- and Golden Retrievers, 94 degrees in German Shepherds and 98 degrees in Rottweilers.

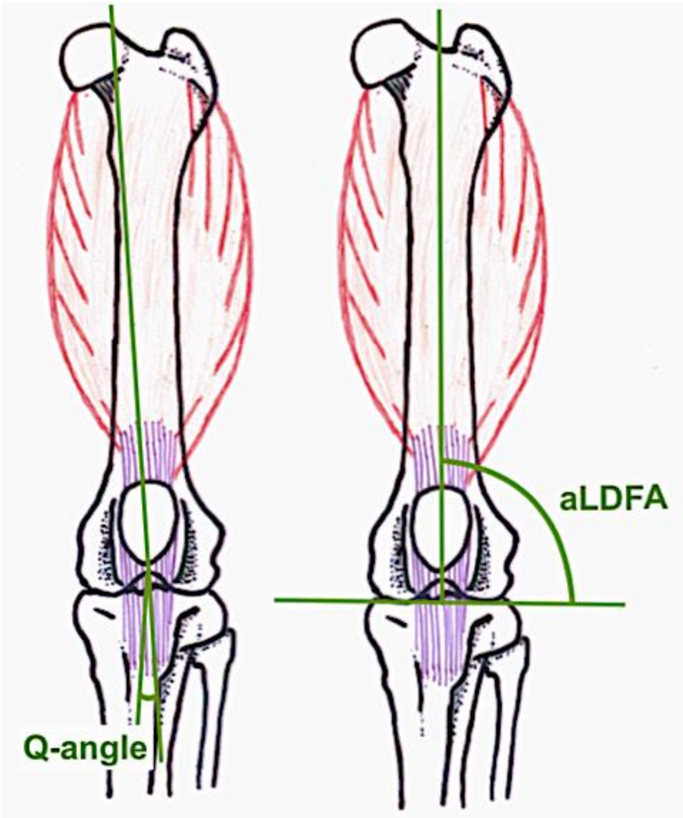

Figure 1: *Illustrations of the Q-angle and the aLDFA in a normal stifle joint.*

The angle formed between the femoral shaft and the femoral head and neck in the frontal plane is called the angle of inclination (AOI) (Hauptman *et al.*, 1979). The AOI is measured in a ventrodorsal radiograph. There are two methods that can be used to measure the AOI. The mean AOI by the method preferred by the authors was 146.2 degrees in a population of 108 dogs. The other method gave an angle of 129.4 degrees. Another study reported the AOI to range from 137 to 155 degrees (Montavon *et al.*, 1985). In Pomeranians, the mean AOI is 136.5 (Soparat *et al.*, 2012). In Labrador- and Golden Retrievers the mean AOI is 134 degrees, German Shepherds has a mean angle of 132 degrees and Rottweilers has a mean angle of 137 degrees (Tomlinson *et al.*, 2007). Coxa valga is an increased AOI, whereas coxa vara is a decreased AOI (Hulse, 1993).

The angle of anteversion represents the angle between the femoral neck and the femoral condyles in the axial view (Hulse, 1993). This angle measures femoral torsion. Anteversion is an external rotation of the proximal femur in relation to the distal femur. Retroversion is an internal rotation of the proximal femur. The mean angle of anteversion in adult dogs is 31.3 degrees according to Montavon *et al*. (1985) and 27 degrees according to Nunamaker *et al*., (1973).

Pathophysiology

Patellar luxation is often classified as congenital or traumatic. However, the correct terminology is to call it developmental since patellar luxation typically is not present at birth even if the skeletal deformities may be present (Kowaleski *et al.*, 2012). Developmental patellar luxation is much more common than traumatic patellar luxation (Hayes *et al.*, 1994).

A number of musculoskeletal deformities have been associated with MPL in the literature but the pathophysiology is still not entirely understood (Kowaleski *et al.*, 2012; DeCamp *et al.*, 2016) The deformities include coxa vara, a decreased angle of anteversion, malalignment of the extensor mechanism/medially increased Q-angle, coxa valga, femoral varus, genu varum, a shallow trochlear groove, a poorly developed medial trochlear ridge, hypoplasia of the medial femoral condyle, medial displacement of the tibial tuberosity, an internal rotation of the tibia, proximal tibial varus, an internal rotation of the foot and abduction of the hock (Singleton, 1969; Kowaleski *et al.*, 2012; DeCamp *et al*., 2016). Patellar luxation may be thought of as a symptom due to developmental diseases of the femur or tibia during growth.

The trochlear groove has an abnormal development in dogs with MPL (Singleton 1969; Hulse 1993). The appearance of the trochlear groove varies from a normal groove to an absent or even a convex trochlea depending on the severity of the luxation and the age of the patient at the onset of luxation. Increased pressure on articulate cartilage retards growth and decreased pressure accelerates growth (Hulse, 1993). If the patella does not exert pressure on the trochlear groove during growth of the dog, the trochlear groove is unable to develop its proper shape and depth. For example, in grade 1 MPL the patella is situated in the trochlear groove resulting in minimal anomaly. Increased pressure across the medial condyle may result in hypoplasia of the condyle. Patellar luxation and reduction cause erosion on the medial trochlear ridge and the patella, resulting in a progressively less apparent medial ridge, crepitation and development of osteoarthrosis (Singleton, 1969).

The most well-known theory regarding the underlying pathophysiology of MPL suggests that coxa vara and a decreased angle of anteversion are the underlying skeletal abnormalities causing secondary changes (Putnam 1968; in Roush, 1993; Kowaleski *et al.*, 2012). These abnormalities result in a medial displacement of the quadriceps muscle group resulting in abnormal forces on the distal femoral physis, inhibiting growth on the medial side, which leads to distal femoral varus and internal rotation of the tibia. Yasukawa *et al.* (2016) showed that Toy Poodles with severe MPL have a medial displacement of the tibial tuberosity and internal torsion of the proximal tibia. Fitzpatrick *et al.* (2012) documented a positive correlation between tibial torsion and increased severity of MPL in Yorkshire Terriers. The Q-angle is medially increased in dogs with MPL (Kaiser *et al.,* 2001; Mortari *et al.,* 2009). This means that the direction of force from the quadriceps muscle is medially deviated pulling the patella medially. The Q-angle in a stifle joint with MPL is illustrated in Figure 2.

Olimpo *et al.* (2016) measured aLDFA in small breed dogs with different degrees of MPL and dogs without MPL. The authors found significantly different values in the group with grade 4 MPL compared to dogs in the other groups indicating that dogs with MPL usually have distal femoral varus. Soparat *et al.* (2012) also found significant different values when measuring the FVA and the aLDFA in Pomeranians with grade 3 MPL compared to Pomeranians without MPL. The aLDFA in a stifle joint with MPL is illustrated in Figure 2. Yasukawa *et al.* (2016) reported that Toy Poodles with grade 4 MPL have femoral varus. Another study found no significant differences when measuring distal femoral varus in small breed dogs with normal stifles compared to small breed dogs with grade 3 MPL (Fasanella *et al.,* 2001; in Soparat *et al.,* 2012). Olimpo *et al.* (2016) found no significant difference in the angle of inclination or angle of anteversion. Neither Soparat *et al.* (2012) or Yasukawa *et al.* (2016) found any difference in the angle of inclination between dogs with normal stifles and dogs with MPL.

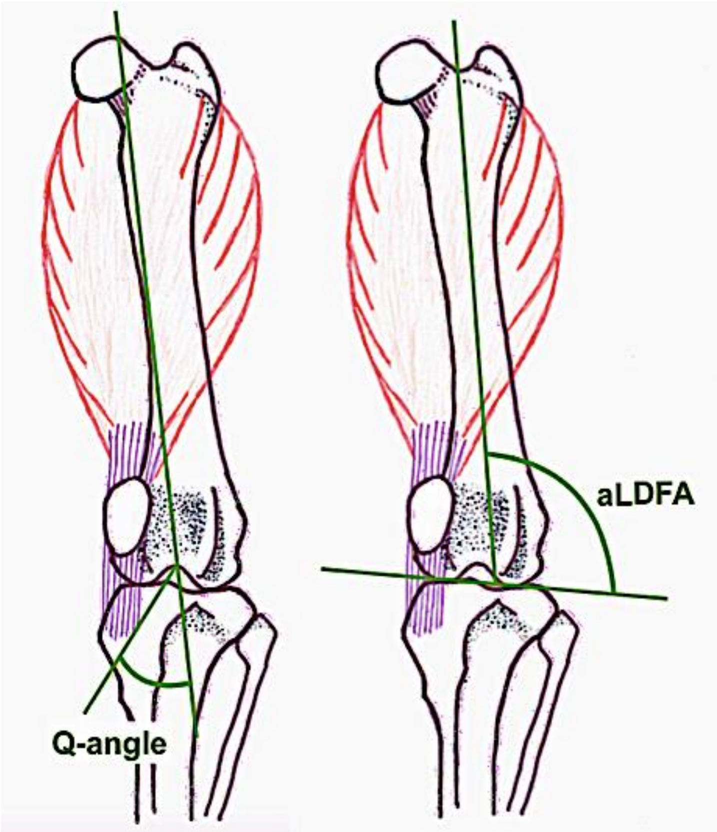

Figure 2: *Illustrations of the Q-angle and the aLDFA in a stifle joint with MPL.*

Bound *et al.,* (2009) reported results that contradict the well-known theory that includes coxa vara. They identified coxa valga as a risk factor for MPL in small breed dogs. The majority of dogs in the study had normal hip conformation or coxa valga. The lower the weight of the dog, the greater degree of coxa valga was present. The authors suggested that the anatomical deformities that cause MPL might be a stifle problem only. The study also showed a significant difference in the conformation of the stifle joint related to genu varum in dogs with patellar luxation compared to the control dogs.

The length, depth, and the volume of the patella are lower in Toy Poodles with severe MPL compared to normal Toy Poodles (Yasukawa *et al.,* 2016). The authors suggest that improper articulation of the patella in the trochlear groove leads to patellar hypoplasia. There was no indication of the severity of MPL being associated with patella alta. Patella alta means that the patella rides proximal in the femoral trochlea (DeCamp *et al*., 2016).

Epidemiology

In a recent study with 8 694 canine orthopedic cases in Italy, 9.2% of the cases had patellar luxation (Bosio *et al.,* 2017). In an epidemiological study by LaFond *et al.* (2002), patellar luxation was the third most commonly diagnosed developmental orthopedic disorder in dogs, and accounted for 18.1% (n = 4 419) of the cases.

According to Bosio *et al.* (2017), patellar luxation is unilateral in 57% of the dogs and bilateral in 43 % of the dogs. Alam *et al.* (2007) found no difference between the prevalence of unilateral (49%) and bilateral (51%) patellar luxation. Gibbons *et al.* (2006) reported that 50% of the dogs had unilateral luxation and 50% had bilateral luxation in a study including dogs >15 kg of bodyweight. Hayes *et al.* (1994) found that patellar luxation was bilateral in 65% of the dogs. In a study including only Pomeranians, MPL occurred bilaterally in 93% of the cases (Wangdee *et al.,* 2013)

MPL is more common than LPL regardless of body weight (Hayes *et al.,* 1994; Alam *et al.,* 2007; Bosio *et al.,* 2017). Different studies have reported a similar proportion of patellar luxation being medial in all weight groups combined, 85% according to Bosio *et al*. (2017) and Alam *et al.* (2007), 89% according to Hayes *et al.* (1994). The risk of LPL increases as breed size increases (Hayes *et al.,* (1994). Even if LPL is more common in large breed dogs than in small and medium breed dogs, it is still more common for large breed dogs to have MPL (73%) than LPL (27%) (Bosio *et al.,* (2017). Another study including dogs >15 kg of body weight showed that 97% had MPL and only 3% had LPL (Gibbons *et al.,* 2006).

Breed and body weight

A number of studies have presented many different breeds affected by patellar luxation. The breed with the highest predisposition for patellar luxation differs between studies. The divergence probably reflects differences in the population in different countries and areas (Bosio *et al.,* 2017). The largest epidemiological study evaluating breed susceptibility included 4 419 dogs with patellar luxation, medial or lateral (LaFond *et al.,* 2002). Thirty-two different breeds turned out to be at increased risk. The breeds with an odds ratio >5 are in descending order the Great Pyrenees, the Pomeranian, the Silky Terrier, the Miniature Pinscher, the Toy Fox Terrier, the Chinese Shar-Pei, the Toy Poodle, the Cavalier King Charles Spaniel, the Papillon, the Yorkshire Terrier, the Australian Terrier, the Akita, the Maltese, the Chow Chow, and the Bulldog (English). In the study by Bosio *et al.* (2017) the most common breed was mixed-breed (19.6%), followed by the Cavalier King Charles Spaniel, the Miniature Pinscher, the Chihuahua, the Miniature or Toy Poodle, the Labrador Retriever, the German Shepherd, the English Bulldog, the Yorkshire Terrier and the Boxer. In total there were 73 breeds diagnosed with patellar luxation. Hayes *et al.* (1994) reported an increased risk of patellar luxation in Miniature and Toy Poodles and Yorkshire Terriers. In another study with 124 dogs treated surgically the most affected breeds were the Cavalier King Charles Spaniel, the Poodle, the Maltese, and the Labrador Retriever (Cashmore *et al.,* 2014). Priester (1972) concluded that the Pomeranian, the Yorkshire Terrier, the Chihuahua, the Miniature and Toy Poodle and the Boston Terrier have an increased risk of patellar luxation. The latter study included patient records from 69 245 dogs and 542 were diagnosed with patellar luxation (medial or lateral). Vidoni *et al.* (2005) documented an increased risk for Miniature and Toy Poodles. Alam *et al.* (2007) found an over-representation of MPL in Chihuahuas and Poodles. Denny & Minter (1973) found the Poodle to be most commonly affected by MPL followed by the Labrador Retriever.

The Orthopedic Foundation for Animals (OFA) reports statistic over dogs that have been evaluated for patellar luxation the United States of America (OFA, 2017). Among the dogs born 2011-2015, the Pomeranian is the breed with the highest ranking with 36.2% of the examined dogs being affected by patellar luxation. Other breeds with >10% being affected by patellar luxation are the Yorkshire Terrier (23.4%), the Australian Terrier (19.0%), the Tibetan Spaniel

(11.8%), the Cocker Spaniel (11.6%), and the English Toy Spaniel (10.1%). The Swedish Kennel Club (SKK) presents statistic over dogs that have been evaluated for patellar luxation in Sweden (SKK, 2017a). In Table 1, data for some of the most commonly affected breeds have been compiled. Additional data for other breeds are available but not presented due to the low number of registered results. Worth noticing is that the Yorkshire Terrier only had 14 registered results out of 996 dogs born during the time period, values are missing from the year 2011 and 2014. The results are still presented since the Yorkshire Terrier is one of the most commonly affected breeds, as previously described.

Table 1: *Swedish patellar luxation statistics, dogs born year 2011-2015*

Breed	**Proportion examined/born**	**Proportion normal patella/examined**	**Proportion MPL/examined**
Australian Terrier	24.3 %	80.5 %	18.6 %
Bichon Frisé	13.5 %	83.9 %	14.9 %
Bichon Havanese	17.5 %	91.3 %	7.8 %
Boston Terrier	44.0 %	84.9 %	14.8 %
Cavalier King Charles Spaniel	20.4 %	95.1 %	4.9 %
Chihuahua	32.2 %	79.9 %	19.8 %
French Bulldog	34.7 %	90.0 %	9.6 %
German spitz, Kleinspitz	33.2 %	83.5 %	16.5 %
German spitz, Pomeranian	8.3 %	59.5 %	40.5 %
Little Lion Dog	40.8 %	79.3 %	20.7 %
Nederlandse Kooikerhondje	28.2 %	94.1 %	5.3 %
Papillon	23.3 %	93.1 %	6.9 %
Phalène	23.5 %	93.0 %	7.0 %
Poodle, medium/miniature/toy	15.7 %	90.8 %	8.8 %
Pug	5.1 %	98.0 %	2.0 %
Russian Toy	37.8 %	84.6 %	15.4 %
Yorkshire Terrier	1.4 %	50.0 %	50.0 %

The table presents the proportion of dogs that have been examined for patellar luxation among all dogs born year 2011-2015 within different breeds, the proportion of dogs with normal patellas among the dogs that have been examined, and the proportion of dogs with MPL among the dogs that have been examined. The data is compiled from statistics available at SKK's webpage in November 2017.

In the study by Bosio *et al.* (2017), 52% of the dogs with MPL were small breed dogs up to 9 kg, 21% were medium breed dogs 9.1-18 kg, and 27% were large breed dogs over 18 kg. Hayes *et al.* (1994) reported similar results and concluded that 44% of the dogs with patellar luxation were of small breed, 17% were of medium breed and 39% were of large or giant breed. The risk of patellar luxation was half for medium breeds compared to small breeds, and a quarter for large breeds compared to small breeds. Worth noticing is that the numbers from the latter study include both medial and lateral patellar luxation. Priester (1972) reported that small breed dogs have a 12 times higher risk of patellar luxation than large breed dogs. Vidoni *et al.* (2005)

reported a decreased risk of patellar luxation for each additional kg of body weight and came to the conclusion that miniaturization is a factor in the development of MPL. The study only included small and miniature breeds.

According to Arthurs & Langley-Hobbs (2006), MPL may be increasing in large breed dogs. In the study by Bound *et al.* (2009), the Labrador Retriever was the breed most commonly affected by patellar luxation. The authors believed that the reason could either be an increased prevalence of patellar luxation within the breed or an increased popularity of the breed. Another study evaluating patellar luxation in dogs > 15 kg of bodyweight found the Labrador Retriever to be overrepresented (Gibbons *et al.*, 2006).

Sex

A possible association between sex and the prevalence of MPL is difficult to determine since studies show conflicting results. Bosio *et al.* (2017) reported no significant difference in the prevalence of MPL between females (54%) and males (46%). Vidoni *et al.* (2005) and Wangdee *et al.* (2013) found no correlation between sex and patellar luxation. Hayes *et al.* (1994) concluded that the prevalence of patellar luxation was similar among intact and spayed females and castrated males, but intact males were at lower risk. In total this gave a female:male ratio of 1.5:1. Priester (1972) showed that the risk of patellar luxation for females was more than 1.5 times that of males. Alam *et al.* (2007) reported a female:male ratio of 1.86:1. Bound *et al.* (2009) also reported that females appeared to be at greater risk. Gibbons *et al.* (2006) reported a female:male ratio of 1:1,8 in large breed dogs.

Age

Studies on the association between age and the prevalence of MPL show somewhat contradicting results, even if most authors agree that patellar luxation often is diagnosed in young and young adult dogs. Bosio *et al.* (2017) found that 43% of the dogs were less than one year old when they were diagnosed, 30% were one to three years old and 27% were over three years old. In the studies by Alam *et al.* (2007) and Denny & Minter (1973) a majority of patellar luxations were diagnosed in dogs younger than three years old. Bound *et al.* (2009) reported that the mean age at diagnosis was 26 months. On the contrary Vidoni *et al.* (2005) reported a 1.1 fold increased risk of patellar luxation for each additional year of age.

Diagnosis and clinical signs

Diagnosis of patellar luxation is based on gait evaluation and physical examination (Kowaleski *et al.*, 2012). Gait evaluation is performed to evaluate lameness, overall conformation, and apparent skeletal deformities. Physical examination is performed with the animal in both standing and recumbent position. The stifle joint should be examined with and without tibial rotation and in both flexion and extension. In a study, approximately 29% of the cases were only palpable when the tibia was rotated and a luxated patella was more frequently diagnosed in dogs standing up than in dogs lying down (Vidoni *et al.,* 2005). This could be explained by a malaligned extensor mechanism that draws the patella medially when the dog is standing up. The physical examination should include patellar instability, patellar position both medio-lateral and dorso-ventral, presence of crepitus, degree of tibial tuberosity rotation, limb torsion or angulation, the depth of the trochlear groove, alignment of the extensor mechanism, ability to extend the limb, drawer movement, tibial thrust movement, and joint effusion (Kowaleski *et al.*, 2012; DeCamp *et al.,* 2016).

Radiographic examination is usually unnecessary to confirm patellar luxation but can be useful to assess the degree of degenerative changes (Roush 1993; Kowaleski *et al.*, 2012). In severe cases, radiographs are used to identify and quantify skeletal abnormalities. Radiographs often appear normal in grade 1 and 2. Adequate radiographic positioning is crucial to obtain correct radiographs but positioning may be difficult to achieve if complete extension of the stifle joint is compromised (Dudley *et al.*, 2006; Mortari *et al.*, 2009). An alternative to radiographs is a computed tomographic examination (Dudley *et al.*, 2006). Computed tomography is recommended in addition to radiographs if the stifle cannot be extended, if the patellar luxation is graded as 3 or 4 and if the dog is of large breed.

Grading system

Patellar luxation is classified into four grades. The grading system was originally presented by Putnam in 1968 and was then elaborated by Singleton (1969). Hulse (1981) has elaborated the grading system additionally and Roush (1993) has presented a simplified grading system, both based on the grading system presented by Putnam (1968). The grading system presented in Table 2 is adapted from Singleton (1969).

Table 2: *Patellar luxation grading system*

Patellar grade	Criteria
Grade 1	- The patella can be luxated manually at full extension of the stifle joint but spontaneously returns to the trochlear groove when released - Absence of crepitation - The medial deviation of the tibial tuberosity and rotation of the tibia is minimal - When the patella is reduced, flexion and extension of the stifle is in a straight line with no abduction of the hock
Grade 2	- The patella luxates spontaneously and can be luxated manually. The patella can either be spontaneously reduced by flexion or extension of the stifle, or manually reduced by rotation of the tibia laterally - A slight medial deviation of the tibial tuberosity may exist and the tibia can be medially rotated up to 30 degrees - The hock is slightly abducted when the patella is medially luxated - Over time the luxation causes erosion of the cartilage on the patella and medial trochlea and crepitation becomes apparent
Grade 3	- The patella is permanently luxated but can be manually reduced - The tibia has a medial torsion of 30 to 60 degrees - Flexion and extension of the stifle causes abduction and adduction of the hock - The trochlear groove is very shallow or flattened
Grade 4	- The patella is permanently luxated and can not be manually reduced - The patella lies just above the medial condyle making a gap occur between the patellar ligament and the distal end of femur - The tibia is medially rotated 60 to 90 degrees - The trochlear groove is absent or convex

Lameness

The severity of lameness varies from animal to animal and is related to the severity of the luxation, presence of cartilage erosion and concurrent cruciate ligament disease (DeCamp *et al.,* 2016). Dogs suffering from patellar luxation can be asymptomatic for their entire life (Vidoni *et al.,* 2005). The study showed that 40% of dogs with patellar luxation were asymptomatic. Typical signs of patellar luxation are a sudden reluctance to jump, and skipping lameness, where the animal carries the leg for several steps, stretches it out and then starts walking normally again (Roush, 1993). In more severe cases, the animal may walk with a crouched back, hyperflexed stifle joint and shift the weight to the front limbs. The lameness can be unilateral or bilateral.

Grade 1 luxation does usually not cause lameness and is often an incidental finding on routine physical examination (Kowaleski *et al.*, 2012) or it may cause mild or intermittent lameness (Alam *et al.,* (2007). Grade 2 often causes mild or intermittent to moderate lameness. Grade 3 is associated with mild, moderate or severe lameness and grade 4 is associated with moderate or severe lameness.

Surgical methods

The aim of surgical repair of MPL is to stabilize the patella within the trochlear groove and to realign the quadriceps mechanism (Kowaleski *et al.*, 2012). This can be accomplished with many different techniques, and often a combination of different techniques is used (DeCamp *et al.*, 2016). It is important that the animal has a stable patella before leaving the surgery, otherwise reluxation often occurs. Surgical methods for patellar luxation repair are divided into soft-tissue reconstruction and bone reconstruction. A basic rule of patellar surgery is that skeletal deformities require bone reconstruction, soft tissue reconstruction alone is not sufficient.

Surgical repair is not recommended for asymptomatic patellar luxation in small breed dogs (DeCamp *et al.*, 2016). These dogs respond well to later surgical repair if the dog becomes symptomatic and necessitating surgery. Conservative treatment including physical therapy is the most common treatment for grade 1 patellar luxation (Bosio *et al.*, 2017). There are two conditions for which surgery is recommended in asymptomatic animals, in young puppies with patellar ectopia to decrease the risk of muscle contracture, and in medium to large breed dogs to decrease the risk of trochlear erosion and deformities (DeCamp *et al.*, 2016). Conservative treatment will not be discussed in this paper as the aim is to evaluate surgical outcome.

For dogs with bilateral patellar luxation, surgical repair can be performed with single-session bilateral surgery, or staged bilateral surgery (DeCamp *et al.*, 2016). In small breed dogs, there is no significant difference in overall complication rate, minor and major complication rates, short-term and long-term outcome, between dogs that have single-session bilateral surgery compared to dogs that have unilateral surgery, according to Clerford *et al.*, (2014). This corresponds to the findings by Fullagar *et al.*, (2017) who observed a similar complication rate in dogs that had single-session bilateral surgery, staged bilateral surgery and unilateral surgery. Gallegos *et al.* (2016) reported that single-session bilateral surgery is well tolerated in small breed dogs. Both Gallegos *et al.* (2016) and Fullagar *et al.* (2017) emphasize that further investigation, preferably prospective studies with a greater number of patients are needed to assess long term-outcome of single-session bilateral surgery.

Bone Reconstruction

Trochleoplasty

The medical term trochleoplasty comprises different techniques that are used to make the trochlear groove deeper and to modify the shape of the trochlea (Kowaleski *et al.*, 2012). The aim is to attain a trochlear groove that encloses 50% of the patella between the trochlear ridges. This can be accomplished with or without preserving the hyaline cartilage. Trochleoplasty reduces the frequency of patellar reluxation (Arthurs & Langley-Hobbs, 2006; Cashmore *et al.,* 2014)

Trochlear block recession

Trochlear block recession is a cartilage sparing technique that can be used to make the trochlear groove deeper and wider (Kowaleski *et al.*, 2012). With this technique, a rectangular piece of the trochlear groove is cut out (DeCamp *et al*., 2016). The proximal trochlear groove can be made deeper compared to with trochlear wedge recession, and the articular contact between the patella and the recessed trochlea is increased with block recession (Johnson *et al.,* 2001). This is an advantage because the patella usually luxates proximally when the stifle is extended. With block recession, the entire trochlear groove maintains the same width. More hyaline cartilage is preserved compared to with trochlear wedge recession (Talcott *et al.*, 2000). After block recession the entire trochlear groove is covered with hyaline cartilage in the proximo-distal direction. Loss of hyaline cartilage only occurs on the abaxial margins of the trochlear groove, which are non-weight-bearing areas of the trochlea.

Two parallel incisions are made in the cartilage and bone along the widest part of the trochlear ridges using an osteotome or a saw (Kowaleski *et al.*, 2012). The incisions run from the top of the trochlea to just above the origin of the caudal cruciate ligament. An osteotome is used to remove the osteochondral block from the trochlear groove. Subchondral bone is removed from the base of the recipient bed to make it deeper. Subchondral bone can also be removed from the bottom of the osteochondral block to achieve additional recession. The osteochondral block is pressed into place in the recipient bed without fixation.

Trochlear wedge recession

Trochlear wedge recession is also a cartilage sparing technique (Kowaleski *et al.*, 2012). Generally, it is based on the same principle as block recession with the removal of subchondral bone to create a recess. In this technique, a V-shaped osteochondral wedge is removed from the trochlear groove using a saw. The V-shaped defect in the trochlea is then widened with a saw with cuts parallel to the initial osteotomies on one or on both sides. The osteochondral wedge is replaced and pressed into place without fixation.

With trochlear wedge recession, the articular surface progressively comes to a point in the proximal and distal margins of the trochlear groove (Johnson *et al.,* 2001). When the stifle is extended the patella moves proximally and may ride on the non-recessed part of the trochlea. If the patella is located medial to the proximal medial trochlear ridge at the beginning of flexion, the patella will continue to luxate medially as the stifle joint flexes (Slocum & Slocum, 1993). To resolve this problem, the proximal trochlear groove can be widened with a rasp, resulting in loss of hyaline cartilage. Whether the proximal trochlear groove is widened or not, loss of hyaline cartilage occurs both in the proximal, distal and abaxial margins of the osteochondral wedge, often exposing subchondral bone within the weight-bearing area of the trochlear groove (Talcott *et al.,* 2000).

Trochlear chondroplasty

Chondroplasty is a technique that can be performed in young dogs, up to 6 months of age according to Kowaleski *et al.*, (2012) and up to 10 months of age according to DeCamp *et al*., (2016). The cartilage is less adherent to the subchondral bone in puppies and a "cartilage flap" can be elevated from the trochlear groove, maintaining its distal attachment. Subchondral bone is removed and the flap then is pressed back into place. The aim of this technique is to deepen the sulcus while preserving the cartilage.

Trochlear sulcoplasty

By this method, the hyaline cartilage and several millimetres of subchondral bone in the trochlear groove are removed (DeCamp *et al*., 2016). The defect will eventually be lined with fibrocartilage. Although the cartilage is removed it can still be a successful method in small dogs and cats (Kowaleski *et al.,* 2012). In an experimental study, dogs treated with trochlear sulcoplasty had a slower return to function compared to dogs treated with trochlear wedge recession (Boone *et al.,* 1983). In all stifles treated with sulcoplasty, crepitus was apparent postoperatively. None of the stifles treated with wedge recession had crepitus.

Tibial Tuberosity Transposition

Medial deviation of the tibial tuberosity can be corrected to create a more stable patella by a transposition of the tuberosity to a more cranial position (Kowaleski *et al.*, 2012). The aim with tibial tuberosity transposition (TTT) is to correct an anatomic abnormality and to realign the quadriceps mechanism (Arthurs & Langley-Hobbs, 2006). To assess the degree of deviation and the movement of the patella in the trochlear groove the animal is placed in dorsal recumbency with the hip, stifle and hook in a neutral position (Kowaleski *et al.,* 2012). In a normal stifle joint, the line of action of the patellar ligament from the patella to the tibial tuberosity is centered over and parallel to the trochlear groove. In animals with MPL, the patellar ligament often has an oblique direction from proximo-lateral to disto-medial. In these cases, a transposition is warranted. Arthurs & Langley-Hobbs (2006) showed that TTT leads to a lower frequency of patellar reluxation and other major complications requiring further surgery. They suggest that TTT should be considered in all corrective surgery for patellar luxation. Campbell & Pond (1972) came to the conclusion that even if there is only a slight deviation of the tibial tuberosity a TTT should be performed. Linney *et al.* (2011) reported that TTT probably is the most important procedure in corrective surgery for MPL.

The skin and the periosteum are incised on the medial side (Kowaleski *et al*., 2012). The incision in the periosteum is made along the tibial tuberosity from 3-4 mm proximal to the attachment of the patellar ligament to the distal extent of the tibial crest. Radiographs can be used to plan the placement of the osteotomy line in advance. The osteotomy is performed with an osteotome, a sagittal saw or bone-cutting forceps. At the distal extent of the tibial tuberosity, the periosteum can be left intact or the osteotomy can be completely separated from the tibia (DeCamp *et al*., 2016). If the periosteum is left intact the osteotomy can only be swivelled instead of completely moved laterally. Kowaleski *et al.* (2012) prefers leaving the distal periosteal attachment intact. There are a few different methods for fixation of the transposed osteotomy that has shown to be clinically successful (Kowaleski *et al.*, 2012). One option is to remove a triangular piece of the tibia from the lateral aspect of the tibial tuberosity 5-8 mm distally from the proximal end of the osteotomy (DeCamp *et al*., 2016). This creates a notch that the osteotomy can be placed into. The osteotomy is then fixated with two Kirschner wires, one proximal and one distal, through the osteotomy and the tibia. Another option is to use two Kirschner wires without a notch (Kowaleski *et al.*, 2012). Instead, the pins and the osteotomy are fixated by an orthopedic wire / tension band that is inserted caudal and distal to the distal extent of the osteotomy, and around the pins in a figure of eight pattern. Regardless of which method is used, it is important that the pins are not placed intra-articular. Cashmore *et al.* (2014) concluded that osteotomies stabilized with a single Kirschner wire without a tension band are 11 times more likely to avulse compared to osteotomies stabilized by two wires. Routine removal of all implants has been reported (Linney *et al.,* 2011) but most authors agree that routine implant removal is not recommended because it would lead to unnecessary surgery (Gibbons *et al.,* 2006; Cashmore *et al.,* 2014)

Femoral osteotomy

Corrective osteotomy is performed to correct distal femoral varus and to decrease the lateral distal femoral angle (Brower *et al.* (2017). There are different techniques described on how to perform an osteotomy but the method most preferred is the lateral closing wedge osteotomy technique (Swiderski & Palmer, 2007; Kowaleski *et al.*, 2012; Brower *et al.,* 2017). The osteotomy is performed latero-distal on the femur. The distal segment should be large enough to accommodate at least three plate screws, without interfering with other procedures performed in the stifle joint. After the proximal and distal segments are reduced, a bone plate is applied to the lateral aspect of the femur. The target angle should be the breed specific normal angle (Brower *et al.,* 2017). If no breed specific angle is available the target angle should be approximately 94 degrees. The healing of corrective osteotomy is predictable and relatively rapid, probably because that the femur is well-vascularized in the metaphyseal region (Swiderski & Palmer, 2007).

Traditionally, corrective femoral osteotomy has been performed in large breed dogs with distal femoral varus or genu varum (Kowaleski *et al*., 2012). Olimpo *et al.* (2016) reported that small breed dogs with grade 4 MPL could benefit from corrective osteotomy since they usually suffer from distal femoral varus. But according to Wangdee *et al.* (2013), corrective osteotomy is challenging in dogs weighing less than 3 kg and with a large femoral angle. Bosio *et al.* (2017) performed corrective osteotomy in addition to other techniques in dogs of different breeds and sizes with patellar luxation grade 3 and 4. They reported the highest prevalence of poor outcome in the dogs with grade 3 that did not undergo corrective osteotomy. Brower *et al.* (2017) and Swiderski & Palmer (2007) found corrective osteotomy to be successful in treating dogs with patellar luxation associated with distal femoral varus, when used in combination with other surgical methods. The lateral distal femoral angle was measured pre and post surgery in the study by Browser *et al.* (2017). Pre-surgery the mean value was 107.6 degrees and post-surgery the mean value was 94.1 which is within normal reference values.

The decision on whether to perform a corrective osteotomy in addition to other techniques has to be addressed from case to case (Brower *et al.,* 2017). The authors do not recommend using a cut off value for aLDFA because the appropriate surgical methods depend on the anatomy and other skeletal deformities of the animal. Perry *et al.* (2017) argues that the selection criteria for when to perform corrective osteotomy require refinement, and they concluded that traditional corrective techniques appear to be sufficient for most cases of MPL.

Soft-Tissue Reconstruction

Desmotomy and capsulotomy

Desmotomy means releasing the retinaculum on the contracted side toward which the patella is luxated, i.e. the medial retinaculum for animals with MPL (Kowaleski *et al.*, 2012). The retinaculum is the fascia and other soft tissue that stabilize the patella. Capsulotomy means releasing the joint capsule on the contracted side toward which the patella is luxated. A contraction in the retinaculum and the joint capsule may cause the patella to move obliquely in the trochlear groove during flexion and extension of the stifle (DeCamp *et al.,* 2016). The purpose of desmotomy and capsulotomy is to relieve all medial tension on the patella and to make it easier for the patella to move in a straight line parallel to the trochlear groove. These procedures should only be used in combination with other corrective techniques. In a study by Arthurs & Langley-Hobbs (2006) desmotomy and capsulotomy resulted in a higher frequency of complications requiring revising surgery. It was suggested that the reason is reduced soft tissue support of the quadriceps mechanism and the patella but this could not be proven. In several other studies where soft tissue release has been used, an increase in complication rate has not been reported, nor has it been stated that soft tissue release does not affect complication rate (DeAngelis & Hohn, 1970; Willauer & Vasseur 1987; Gibbons *et al.,* 2006; Cashmore *et al.,* 2014).

Quadriceps Release

In severe cases of MPL, the quadriceps mechanism may be so misaligned that it creates tension that medially displaces the patella (DeCamp *et al.,* 2016). In these cases releasing the entire quadriceps muscle from the femur and other muscle tissue can relieve tension.

Imbrication

Imbrication tightens the soft tissue on the opposite side of the luxation i.e. the lateral side in cases of MPL (Kowaleski *et al.*, 2012). The aim is to stabilize the patella in the trochlear groove. The joint capsule, the retinaculum, and the fascia lata can be imbricated. Imbrication of the joint capsule can be made by placing mattress sutures 3-4 mm from the incision of the joint capsule or by placing sutures in a vest-over-pants pattern. If this is not sufficient, a partial capsulectomy can be carried out and imbrication is performed afterward. This applies to the fascia lata as well, imbrication can be made without removing excess tissue or by performing a partial fasciectomy. Campbell & Pond (1972) showed that imbrication alone is not sufficient if there is a deviation of the tibial tuberosity of any degree.

Anti rotational sutures

A non-absorbable suture can be placed behind the lateral fabella and around the patella to create a synthetic ligament that stabilizes the patella (DeCamp *et al.,* 2016). Another suture can be placed behind the lateral fabella and in the distal patellar ligament or in the tibial tuberosity. The latter suture prevents tibial rotation. The surgeon should position the leg in different degrees of flexion to find the angel that causes the most tibial rotation. The possibility to choose different insertion points makes it possible to place the suture so that it is taut when the stifle is flexed to that angle. These anti rotational sutures will eventually loosen or break in most cases but the new position of the patella and tibia can be maintained by fibrous tissue and realignment of soft tissues.

Other less frequently used methods

In severe cases of tibial torsion a proximal tibial derotational osteotomy can be performed (Pérez & Lafuente 2014). The osteotomy is fixated by a bone plate. However, this method is rarely used. The release of the cranial belly of the Sartorius muscle may reduce the rate of patellar reluxation and can be performed in addition to other techniques (Cashmore *et al.,* 2014). Although it has been recommended to perform Sartorius release during patellar stabilization (Horne, 1979), the technique is rarely used.

Patellectomy is a technique that only should be considered when the dog has not improved clinically after other surgical procedures and erosion is severe (DeCamp *et al.,* 2016). Patellectomy results in degeneration of the trochlear articular cartilage, relative quadriceps muscle insufficiency and loss of stability in the stifle joint (Hulse, 1993). When performing patellectomy, a vertical incision is made over the midline of the patella (DeCamp *et al.,* 2016). The quadriceps tendon, retinaculum, joint capsule and patellar ligament are peeled off the patella. The defect is then closed with non-absorbable sutures.

Patellar groove replacement is a newly developed method for treating patellar luxation in dogs with severe degenerative joint disease (Dokic *et al*., 2015). The degenerated trochlear groove of the femur is removed and replaced with a trochlear prosthesis. The prosthesis can be positioned to find the best alignment with the extensor mechanism and in this way stabilize the patella. The method has the potential to improve function in stifle joints with severe degenerative joint disease.

Postoperative care

A soft padded bandage is used for 2-3 days after surgery (Kowaleski *et al.*, 2012). In very active patients a bandage can be maintained for 10-14 days (DeCamp *et al.,* 2016). Nonsteroidal anti-inflammatory drugs (NSAIDs) is prescribed for 10-14 days. Activity is restricted for 4-6 weeks post surgery while bone healing occurs (Kowaleski *et al.*, 2012). Bone healing should be evaluated radiographically 6-8 weeks after surgery if TTT or femoral osteotomy has been performed (DeCamp *et al.,* 2016). Active physical therapy is appropriate for the first 6-8 weeks.

Prognosis

The severity of MPL is probably the most important factor to consider regarding the prognosis after surgery, according to Hans *et al.* (2016). Bosio *et al.* (2017) concluded that grade 1 and grade 2 patellar luxation had the best surgical results two months after surgery with a good outcome in 92% of the cases. The total reported outcome was good in 88% of all stifles. A good outcome was defined as patellar stabilization and complete functional recovery.

Alam *et al.* (2007) documented the outcome to be excellent (full weight-bearing with no gait abnormality) or good (full weight-bearing with mild or intermittent gait abnormality) in 94% of all cases on the follow-up examination 4 to 16 weeks post-operatively. Lameness was improved in 94% of the cases, and unchanged or worsened in 6% of the cases.

Gibbons *et al.* (2006) reported short-term outcome (less than three months) to be excellent/good in 83% of the cases and long-term outcome (over three months) to be excellent/good in 94% of the cases in surgically treated dogs with a body weight above 15 kg. Some of the dogs that had fair/poor short-term outcome had revision surgery. The grade of patellar luxation did not significantly affect the long-term outcome in the study.

There are fewer reports describing clinical results after surgical correction of grade 4 MPL than less severe grades of MPL. In the study by Hans *et al.* (2016) that included 47 stifles with grade 4 MPL, clinical outcome was classified as full limb function for 42.6% of the stifles, acceptable limb function for 40.4% of the stifles and unacceptable limb function for 17% of the stifles. The follow-up examination was carried out 30-179 days after surgery. The authors came to the conclusion that surgical correction of grade 4 MPL typically improves limb function, but a return to full limb function should be considered guarded. Unacceptable limb function was not affected by any of the evaluated clinical variables, i.e. age, body weight, bilateral grade 4 MPL, cranial cruciate ligament rupture, or performing a corrective osteotomy. In the study by Bosio *et al.* (2017) the outcome after surgical correction of grade 4 patellar luxation was good in 87% of the cases, fair in 1 % of the cases and poor in 12% of the cases. The classifications used by Bosio *et al.* (2017) and Hans *et al.* (2016) might not be completely comparable since the definitions deviate.

Brower *et al.* (2017) performed long-term follow-up interviews after patellar luxation treatment with corrective osteotomy in addition to other techniques, and documented excellent client satisfaction. The success rate was 9.6/10 according to the owners. The lowest scores in the interview were related to stiffness. The study included 55 dogs, a majority were of large breed with MPL grade 2-4. Swiderski & Palmer (2007) performed a similar study and reported that the owners ranked the outcome of surgery to 8.8/10 long-term. The latter study only included 16 dogs with a body weight above 18 kg, two dogs were diagnosed with MPL grade 2 and 13 dogs were diagnosed with MPL grade 3. All 16 dogs were treated with corrective osteotomies in addition to other techniques.

Complications

Postoperative complications are often classified as major or minor complications. Major complications are defined as complications that require revision surgery and minor complications are those that do not require further surgery (Arthurs & Langley-Hobbs, 2006). Different studies have documented similar numbers in overall complication rate, major and minor complications. The overall complication rate is 18% according to Arthurs & Langley-Hobbs (2006), 21% according to Bosio *et al.* (2017), 23.2% according to Perry *et al.* (2017), and 24% according to Fullagar *et al.* (2017). The documented frequencies of major complications are 13% (Arthurs & Langley-Hobbs, 2006), 16% (Bosio *et al.,* 2017), 18.5% (Cashmore *et al.,* 2014), 4.9% (Perry *et al.,* 2017), and 9% (Fullagar *et al.,* 2017). The documented frequencies of minor complications are 5% (Arthurs & Langley-Hobbs, 2006; Bosio *et al.,* 2017), 17.6% (Perry *et al.,* 2017), and 15% (Fullagar *et al.,* 2017).

In a study evaluating outcome following surgical correction of grade 4 MPL, complications occurred in 25.5% of the cases and revision surgery was required in 12.8% of the stifles (Hans *et al.,* 2016). This number is lower compared to the study by Arthurs & Langley-Hobbs (2006), which reported that 32% of the stifles with grade 4 MPL needed revision surgery. In a study with surgically treated dogs with a body weight above 15 kg, complications were observed in 28.6% of the cases, 10% were major and 19% were minor complications (Gibbons *et al.,* 2006).

Patellar reluxation

In several studies, patellar reluxation is the most common complication (Arthurs & Langley-Hobbs, 2006; Gallegos *et al.,* 2016; Bosio *et al.,* 2017). In the study by Arthurs & Langley-Hobbs (2006), patellar reluxation accounted for 65 % of major complications. Additionally patellar reluxation that did not require revision surgery also occurred. Overall, patellar reluxation was the most common complication followed by implant-related problems. The incidence of patellar reluxation was similar in the study by Cashmore *et al.* (2014) where patellar reluxation occurred in 11.6% of the cases and 6.4% required revision surgery. In the study by Bosio *et al.* (2017) patellar reluxation occurred in 7% of the cases. Hans *et al.* (2016) documented patellar reluxation in 10.6% of the stifles with the preoperative grade 4 MPL, but only 4.3% required revision surgery. In the study by Gibbons *et al.* (2006) patellar reluxation occurred in 9% of the dogs. Wangdee *et al.* (2013) reported a reluxation-rate of 10% in Pomeranians. The dogs that were affected by reluxation had a preoperative grade of 3 or 4. Perry *et al.* (2017) reported a lower rate of patellar reluxation compared to most previous studies. The only case of patellar reluxation (1.2%) was subclinical and did not require additional surgery. In the study by Roy *et al.* (1992) none of the surgically treated stifle joints (n = 12) had a reluxating patella at the follow-up examination.

The risk of patellar reluxation increases if trochleoplasty is not performed (Arthurs & Langley-Hobbs, 2006). Cashmore *et al.* (2014) discovered that patellar reluxation is five times more likely if trochleoplasty is not performed. Both Brower *et al.* (2017) and Swiderski & Palmer, (2007) had zero cases of patellar reluxation after performing corrective femoral osteotomy in combination with other techniques.

Willauer & Vasseur (1987) studied the long-term clinical outcome in dogs that had corrective surgery for MPL by examining the dogs at least one year after surgery. Patellar reluxation was observed in 25 out of 52 stifle joints, 17 of these were grade 1. Interesting was that only three out of 34 dogs were lame at the follow-up examination. The proportion of patellar reluxation in this study differs from many others studies, which have reported lower numbers. In some of the other studies (Arthurs & Langley-Hobbs, 2006; Cashmore *et al* 2014) a follow-up examination was not performed in all patients, instead only dogs presented with symptoms were examined, or a follow-up evaluation was based on interviews with the owners.

Implant related complications

Cashmore *et al.* (2014) reported implant related complications to be the most common but least severe complications followed by patellar reluxation. The implant related complications accounted for 37.5% of major complications and affected 8.1% of the stabilizations. Arthurs & Langley-Hobbs (2006) reported implant related complications to be the second most common complication. Implant related complications can be classified as severe i.e. implant failure, or less severe i.e. other implant related problems such as discomfort or seroma formation (Gibbons *et al.*, 2006). In the study by Bosio *et al.* (2017) implant failure was observed in 2.1% of the cases. Brower *et al.* (2017) documented implant failure in 2% of the cases. Gibbons *et al.* (2006) reported 2.8% implant failures and 7.1% less severe implant related problems. Common observed implant related complications are pin migration, broken pins, discomfort, seroma formation, infection, skin irritation and swelling (Gibbons *et al.,* 2006; Alam *et al.,* 2007; Cashmore *et al.,* 2014).

Other complications

Frequently reported major complications are tibial tuberosity avulsion fracture, improper correction of limb deformities, wound dehiscence, septic arthritis and patellar ligament laceration (Alam *et al.,* 2007; Cashmore *et al.,* 2014; Hans *et al.,* 2016; Bosio *et al.,* 2017; Fullagar *et al.,* 2017; Brower *et al.,* 2017). Other less common major complications are fracture of the tibia and fibula, fracture of the femur, non-union, persistent lameness, improper soft tissue release, and lysis of the fracture site (Arthurs & Langley-Hobbs, 2006; Bosio *et al.*, 2017; Brower *et al.,* 2017).

Observed minor complications are surgical site infection (SSI), swollen straight patellar tendon, seroma formation, hock hyperextension, intermittent lameness, delayed functional recovery, muscle contracture, delayed wound healing, and delayed union (Arthurs & Langley-Hobbs, 2006; Gibbons *et al.,* 2006; Alam *et al.,* 2007; Bosio *et al.,* 2017; Fullagar *et al.,* 2017).

Risk factors associated with complications

Luxation grade

An increased severity of luxation is associated with a significantly increased frequency of complications (Cashmore *et al.*, 2014). This means that the prognosis depends on luxation grade and clinical signs. Bosio *et al.* (2017) and Perry *et al.* (2017) also found a correlation between the frequency of major complications and the severity of the luxation. It was suggested by Bosio *et al.* (2017) that the reason the frequency of complications increases in severe cases might be related to a difficulty to correct severe anatomic deformities and to realign the quadriceps mechanism. Cashmore *et al.* (2014) concluded that grade 2-4 had an increased risk of major complications compared to grade 1 but there was no difference in patellar reluxation between different preoperative luxation grades.

Body weight

The frequency of all complications, major complications, and patellar reluxation are significantly higher for dogs weighing 20 kg or more compared to dogs weighing less than 20 kg according to Arthurs & Langley-Hobbs, (2006). Bosio *et al.* (2017) also found an association between body weight and the frequency of complications. Dogs without complications had a lower body weight than dogs with complications. Cashmore *et al.* (2014) found no correlation between body weight and the risk of complications.

Age and sex

Age and sex do not affect the frequency of complications (Arthurs & Langley-Hobbs, 2006; Cashmore *et al.*, 2014; Bosio *et al.,* 2017). The clinical outcome at least one year after surgery was similar in different age groups in a study by Willauer & Vasseur (1987).

Surgical technique

Many reports agree on the fact that trochleoplasty reduces the complication rate (Arthurs & Langley-Hobbs, 2006; Cashmore *et al.,* 2014; Perry *et al.*, 2017). Gibbons *et al.* (2006) discovered that major complications occurred in 6% of the cases that had femoral trochleoplasty, TTT and soft tissue reconstruction, and in 22% of the cases that only had TTT and soft tissue reconstruction.

Linney *et al.* (2011) evaluated the results of surgical correction without trochleoplasty where 19.8% of the dogs had patellar reluxation at the follow-up examination and 6.6% required additional surgery. The occurrence of patellar reluxation is higher than in several other studies (Roy *et al.*, 1992; Gibbons *et al*, 2006; Wangdee *et al.*, 2013; Cashmore *et al.*, 2014; Hans *et al.,* 2016; Bosio *et al.*, 2017; Perry *et al.*, 2017). The time from surgery to follow-up examination varied from 0.3 to 86.9 months, thus making it difficult to draw any conclusions on the long-term effect of corrective surgery without trochleoplasty.

In the study by Hans *et al.* (2016) corrective osteotomy was associated with a higher risk of major complications, but due to the small number of cases, the result should be interpreted with caution. Bosio *et al.* (2017) reported the highest prevalence of poor outcome in the dogs with grade 3 patellar luxation that did not undergo corrective osteotomy. A high frequency of complications related to corrective osteotomy may be related to the fact that corrective osteotomy is only performed in dogs with severe patellar luxation.

Degenerative joint disease

Willauer & Vasseur (1987) discovered that degenerative joint disease was observed in the majority of stifle joints that had undergone corrective surgery for patellar luxation over one year ago. This included both stifle joints with and without patellar reluxation. The changes were usually mild and only 3 out of 34 dogs in the study were lame. These findings are consistent with a report by Roy *et al.* (1992) in which surgical correction of MPL did not prevent progression of degenerative joint disease in the stifle joint. This study compared clinical and radiographic findings in bilaterally affected dogs that had unilateral corrective surgery. Radiographic scores increased in both surgically treated and non surgically treated stifle joints from the pre-operative examination to the follow-up examination (mean time 33 months). Limb use improved in all surgically treated limbs. Worth noticing is that trochlear sulcoplasty, which does not preserve the hyaline cartilage, was used in 10 out of 12 stifle joints. Whether the choice of surgical technique affected the progression of degenerative joint disease could not be concluded.

Assessment of chronic pain and quality of life

It is difficult to assess pain in animals, especially chronic pain (Dobromylskyj *et al.*, 2000). Chronic pain is more difficult to detect than acute pain and the behavioural changes may be subtle. Pain evaluation in animals is based on behavioural observations, but many factors can influence the behaviour. During examination and evaluation, the animal is often situated in a strange environment with unfamiliar smells and other animals close by, which may be perceived as threatening. This may alter the animal's normal behaviour and mask the signs of pain. The absence or presence of the owner may alter the animal's response to pain. Between species and within species the response to pain can be very different. Some dog breeds tend to be more stoical and other breeds seem to be more wimpish. Individual differences within a breed also exist. The character and temperament of the dog will also influence the response. Some individuals may become defensive while others become repressed.

There are different types of pain scales used to evaluate pain in dogs: visual analogue scales, numerical rating scales, simple descriptive scales, and multifactorial descriptive scales (MDS) (Hielm-Björkman, 2007). In addition to pain scales, examination using radiographs, plasma stress hormones or force plates have been used in research to estimate pain in dogs, but these methods seem to be uncertain. Hielm-Björkman (2007) concluded that the MDS questionnaire was the most accurate method to assess chronic pain in dogs. A MDS contains questions relating to different aspects of pain. The answers consist of several alternatives corresponding to the degree of severity. Wiseman *et al.,* (2001) presented the first report on the evaluation of chronic pain in dogs using an owner based measurement. The study included unstructured interviews with 13 owners of dogs with chronic pain. All owners reported changes in their dog's behaviour, for example, changes in mobility, activity, playfulness, demeanour, anxiety, and sociability.

Owner questionnaires have recently been used in several studies to evaluate surgical outcome or to compare surgical techniques or treatment methods in dogs with orthopedic diseases, for example in Boyd *et al.* (2007), Corr & Brown (2007), Renwick *et al.* (2009), Mölsä *et al.* (2013) and Teixeira *et al.* (2016). Two MDS questionnaires that have been validated and are considered to be reliable and responsive are the Helsinki Chronic Pain Index (HCPI) and the Canine Orthopedic Index (COI) (Hielm-Björkman, 2007; Brown, 2014a). The HCPI has been validated for measuring chronic pain caused by degenerative joint disease in dogs (Hielm-Björkman, 2007). The COI was developed to measure domains other than chronic pain in dogs with orthopaedic disease (Brown, 2014b). The COI has been validated for measuring stiffness, gait, function, and quality of life in dogs with degenerative joint disease (Brown 2014a; Brown 2014b; Brown 2014c).

MATERIAL AND METHODS

Case selection in the retrospective study

The study was conducted between February and November 2017. This thesis is a part of a large on-going study evaluating complications after orthopedic surgery. The medical records of dogs that underwent orthopedic surgery at the University Animal Hospital (UDS) in Sweden between January 2012 and December 2015 were selected for the larger study. All medical records of dogs that underwent surgical correction of MPL were manually sorted out and were retrospectively reviewed. Data from the time of diagnosis of MPL to one year post surgery has been documented in a spreadsheet. In cases where medical data was missing for the entire time period, the dog-owners have been interviewed by telephone or by email. A total number of 45 medical records were reviewed. An affected stifle joint treated surgically was defined as one case and animals with bilateral MPL treated surgically in both stifles were considered to be two surgical cases in the retrospective study. None of the bilateral treated animals had single-session bilateral surgery. Planned staged unilateral surgery was also defines as two cases. Dogs with concomitant stifle joint disorders such as cranial cruciate ligament rupture and dogs with LPL were excluded. The total number of cases was 49.

Description of data in the retrospective study

Breed, body weight at the time of surgery, date of birth and gender were recorded. The Fédération Cynologique Internationale (FCI) breed nomenclature was used for registering the breeds. Breeds not recognized by the FCI were regarded as mixed-breed. The luxation was registered as unilateral, bilateral surgically treated or bilateral not surgically treated. All dogs diagnosed with bilateral disease and/or bilateral surgically treated at the time of data registration were accounted for.

The severity of the luxation was classified into four grades according to the grading system described in the literature review. The grade specified in the medical record was used primarily. In cases where the grade was not specified in the medical records, the description of the patellar luxation was compared to the grading system and the most compatible grade was documented. In borderline cases, the less severe of two grades was registered.

Date of surgery, date of discharge, operating surgeon/surgeons, and type of surgery was documented. All techniques utilized for the surgical correction were at the discretion of the operating surgeon. The following techniques were used in different combinations: tibial tuberosity transposition, trochlear block recession, imbrication on the lateral side, soft tissue release on the medial side, and anti-rotational sutures. The usage of implants was documented. An experienced veterinary surgeon or a surgical resident under the supervision of a surgeon performed the surgery. Intraoperative surgical complications such as misplaced implants or loss of sterility were recorded.

The number of clinical returns to a veterinarian at UDS for the first three months after surgery was recorded regardless if the visit was a planned follow-up examination or an unplanned visit. Visits regarding physical therapy were not included in the number of clinical returns, instead this was documented in a separate column. If postoperative aftercare was conducted at another veterinary clinic than UDS, this was also reported.

Postoperative complications within one month and within one year after surgery were recorded. Within one month (0-30 days post surgery) two different complications could be registered and within one year (30-365 days post surgery) one complication could be registered. The most severe complication was registered first. For example, if the dog had persistent patellar luxation, SSI, and mild gastroenteritis, the registered complications were persistent patellar luxation and SSI.

As previously described, patellar reluxation is the most common complication after corrective surgery for MPL in several studies. In this study, patellar reluxation was registered as a complication if the luxation was persistent or increased compared to the preoperative grade. This means that if a dog was diagnosed with MPL grade 2 preoperatively, it was not considered a complication if the dog had MPL grade 1 postoperatively.

Implant-related complications are also common according to many studies previously described. In this report, implant failure was documented but minor implant-related complications such as discomfort or skin irritation have not been documented even if the complication resulted in the removal of the implants. Pin migration or broken pins with proximal displacement of the tibial tuberosity and infected implants were considered to be implant failures. Loose pins a long time post-surgery when healing is complete and without displacement of the tibial tuberosity was not considered to be an implant failure. Implant removal that was planned before surgery was not regarded as a complication.

Degenerative joint disease was not considered to be a complication since corrective surgery for MPL does not prevent the development of degenerative joint disease in stifle joints with MPL (Roy *et al.*, 1992; Willauer & Vasseur, 1987). Mild inflammation, swelling, discomfort, lameness and other unspecific conditions not related to a specific complication were not registered because these are expected consequences of surgery. Lameness and the severity of lameness was not documented post surgery since lameness was not graded with a uniform grading system in the medical records.

Unplanned return to surgery due to the failure of previous surgery was documented in a separate column. For example, this column did not include staged unilateral surgery in young growing dogs, or removal of loose pins that was correctly positioned during the first surgery.

All cases where a bacterial culture was taken post-surgery were recorded even if the culture was negative. The dominant bacterial type was documented if there was dominant bacterial type present. If the bacteria were resistant to antibiotics this was specified. Low to moderate growth of mixed bacterial flora without a dominant bacterial type were classified as mixed bacterial flora / normal bacterial flora.

For all reported complications, the probability of the complication relevant to surgery was classified as low, moderate, or severe. The probability of a complication to occur is increased the period immediately after surgery and decreases with time. The probability is also directly related to the type of complication. The severity of a complication was reported for complications that occurred within one month post surgery. The severity is related to how the complication affects the animal. The probability of complications is illustrated in Table 3 and the severity of complications is illustrated in Table 4.

Table 3: *The probability of complications 0-365 days post surgery*

	Definitions	**Examples**
PROBABILITY		
Severe	Complications that occur shortly after surgery and has a direct causality to the surgery	- Persistent patellar luxation - SSI - Aspiration pneumonia - Implant failure
Moderate	Complications that occur shortly after surgery and has a indirect causality to the surgery, OR, complications that occur a long time after surgery and has a direct causality to the surgery	- Implant failure after healing is complete - Delayed wound healing - Gastroenteritis due to prescription of NSAID
Low	Complications that somehow can be related to the surgery or the hospitalization time but the causality is vague	- Unusual complications - Cystitis after usage of a catheter during hospitalization

Table 4: *The severity of complications 0-30 days post surgery*

	Definitions	**Examples**
SEVERITY		
Severe	Complications with severe negative impact on the patient	- Death - Persistent patellar luxation - Implant failure - Hospitalization for intensive care
Moderate	Complications with moderate negative impact on the patient	- SSI - Moderate gastroenteritis - Moderate to severe excoriations caused by bandage or splint
Low	Complications with mild negative impact on the patient	- Delayed wound healing - Mild gastroenteritis

Mortality within one month and within one year was documented. Cause of death was documented as directly related to the surgery/surgical disease, other cause not related to the surgery/surgical disease, or related to surgery/surgical disease but associated with another disease.

Additional data that is not presented here has been collected and will be analyzed and presented in another study, for example, data regarding medication before, during and after surgery.

Case selection in the quality of life study

All dogs alive at the time of data collection were included in the case group in the quality of life study. A case was defined as a dog treated surgically for MPL within the time-period previously described. Dog-owners with bilaterally treated dogs answered the questionnaire once.

The inclusion and exclusion criteria for the control group were designed to make the controls correspond with the cases. The dogs had to be three years or older since the youngest dogs in the case group were born the year 2014. No breed was excluded but owners of Pugs, French Bulldogs, Chihuahuas, Poodles with a weight below 10 kg and mixed-breed with a weight below 10 kg were encouraged to answer the survey. Dogs with a body weight > 15 kg were excluded. The dogs were not allowed to have undergone any orthopedic surgery, including corrective surgery for patellar luxation. Dogs currently suffering from any orthopedic disorder or pain that causes abnormal movements were excluded, for example, hip dysplasia, elbow dysplasia, fractures or polyarthritis. Other non-orthopedic diseases, for example, respiratory disorders, allergies, cardiovascular diseases etcetera were not excluding. Dogs diagnosed with MPL higher than grade 1 were excluded. Dogs with unknown patellar status were included as long as the owner had not noticed any abnormal movements from the hind legs. The control dogs had to be alive at the time the questionnaire was answered. The control group was found among students at the Swedish University of Agriculture Sciences and through social media.

Collection of data in the quality of life study

Two corresponding online surveys have been created in Google Forms, one survey for the case group and one survey for the control group. The questionnaires are written in Swedish. The surveys are combinations of the HCPI (Hielm-Björkman, 2007) and the COI (Brown, 2014a). The Swedish surveys are currently under validation. Initial contact with the dog-owners was made by email and/or telephone. The purpose of the study was explained and the owners were asked if they could participate in the quality of life study. A link to the questionnaire was sent to the owners by email.

Description of data in the quality of life study

The questionnaires begin with general questions regarding the current health status of the dogs. These questions differ slightly between the survey designed for the case group and the survey designed for the control group. The next section, which includes the questions that are being validated, is composed of 22 questions evaluating the dog's function the last month. These questions were exactly the same for the case group and the control group. All questions were based on the owners' perception of their dogs. Owners of the dogs in the case group were asked to answer the questions with the surgically treated leg in mind. The questions in this section covered the subjects stiffness in the morning and later during the day, ability to stand up and lay down, ability to jump up and jump down, ability to climb up and climb down, lameness during and after different activities, the dog’s mood and willingness to participate in play, the dog’s quality of life as assessed by the owner, and the owners concern for the dog. Each answer was converted into a score and each question could give a score from zero to four. The score zero represented the best alternative for the dog in every question, for example, “no lameness”, “no problems” or “very good”. The score four represented the worst alternative for the dog, for example, “severe lameness” or “non-weight bearing on the surgically treated limb”. All questions had the alternative “don’t know” and some questions had the alternative “not applicable”. The maximum possible score was 88. All questions and alternatives are presented in Appendix 1.

Statistical analysis

Descriptive statistic was used to calculate the percentage of different factors such as patellar grade, surgical methods, frequency of complications, breed distribution and gender. Mean scores for different questions in the questionnaire and the total mean score were calculated. Logistic regression and odds ratio was used to analyze if the factors breed, age, and body weight were associated with postoperative complications. The odds ratio was calculated to evaluate the relation between bilateral disease and postoperative complications. A two-sample *t*-test with unequal variances was used to compare the mean scores of the case group with the mean scores of the control group. A confidence interval of 95 % was used in all analyses. The statistical analyses were executed in Stata and some of the descriptive statistics were calculated in Microsoft Excel.

RESULTS

The retrospective study

Description of cases

Among the 45 dogs reviewed, 21 different breeds were represented. The most common breed was mixed-breed 17.8% (n = 8), followed by the French Bulldog 11.1% (n = 5), the Pug 11.1% (n = 5), the Chihuahua 8.9% (n = 4) and the Poodle 8.9% (n = 4). The breed distribution is presented in Figure 3. The mean age at the time of surgery among all cases (n = 49) were 2.6 years of age. The youngest dog was 7 months old and the oldest dog was 8.9 years old. The mean body weight at the time of surgery among all the cases was 7.4 kg and the body weight varied from 1.8 kg to 30.2 kg. Among the mixed-breed dogs, the mean body weight was 4.6 kg, and the body weight varied from 2.0 kg to 9.2 kg. The gender distribution among all cases were 57.1% males and 42.9% females, 36.7% (n = 18) were intact females, 6.1% (n = 3) castrated females, 30.6% (n = 15) intact males and 26.5% (n = 13) castrated males.

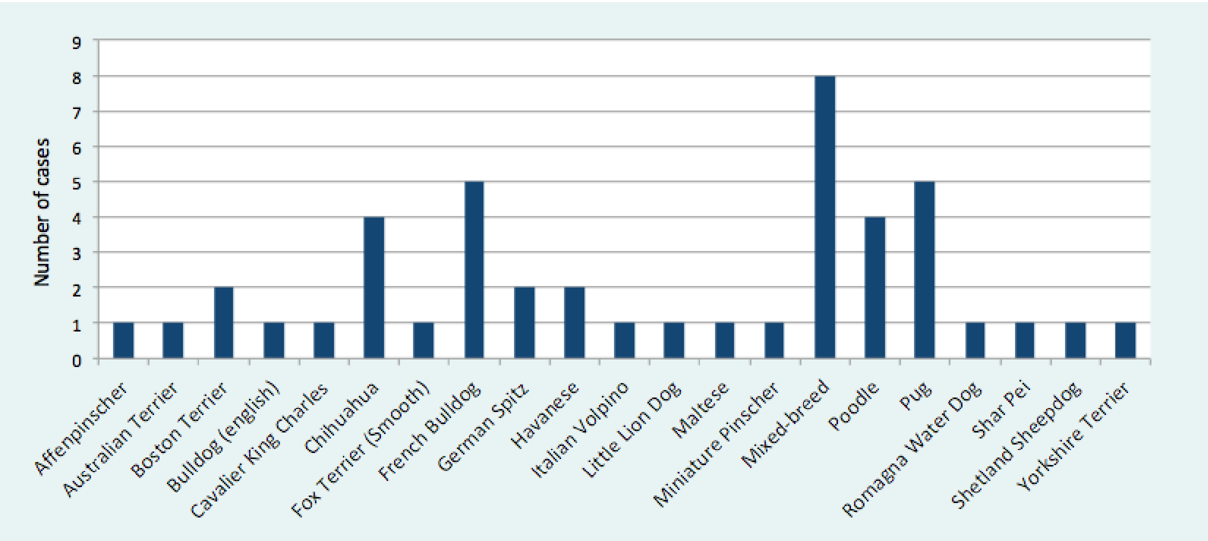

Figure 3: *Breed distribution based on individuals.*

The severity of the luxation was grade 2 in 73.5% (n = 36) of the cases, grade 3 in 24.5% (n = 12) of the cases and grade 4 in 2% (n = 1) of the cases. None of the cases had a patellar luxation grade 1. The patellar luxation was unilateral in 44.4% of the cases and bilateral in 55.6 % of the cases. Among the bilateral cases, 11 cases were treated surgically in both stifles at UDS or at another veterinary clinic and 14 cases only had surgery in one of the stifles. The distribution of patellar grade among dogs with unilateral MPL versus bilateral MPL is presented in Figure 4.

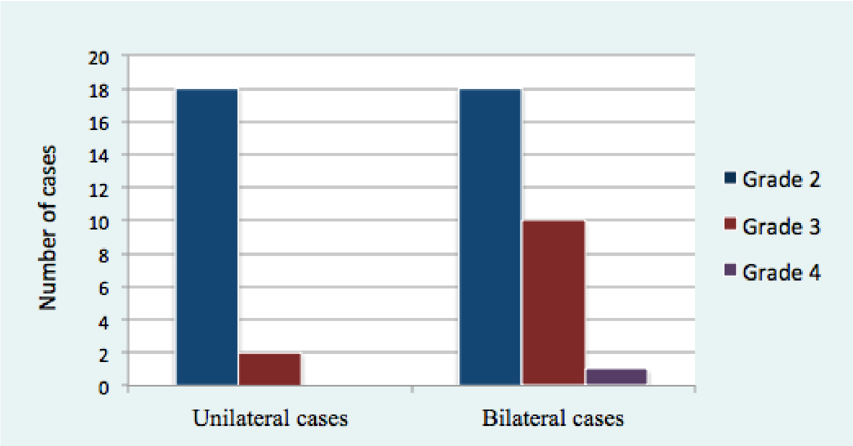

Figure 4: *Distribution of patellar grades, unilateral and bilateral cases.*

Treatment

A combination of different surgical techniques was used in all cases except in one case where only tibial tuberosity transposition was performed. The combination of two techniques was used in 29 cases, three techniques in 16 cases, four techniques in two cases and five different techniques were used in the only case with a grade 4 MPL. The most common combinations were trochlear block recession combined with imbrication (n = 18), TTT combined with trochlear block recession and imbrication (n = 15) and TTT combined with imbrication (n = 9). If TTT was not performed, trochlear block recession was performed in all cases except one. Imbrication was done in all cases but two. A complete list of the surgical methods performed is presented in Table 5. All cases except two visited a physical therapist at UDS or at another veterinary clinic after surgery. There is one missing value regarding physical therapy.

Table 5: *Number of surgical methods performed among all cases*

Surgical methods	**Number of cases**	**Percentage**
Tibial tuberosity transposition	29	59.2
Trochlear block recession	38	77.6
Imbrication	47	96.9
Soft tissue release	4	8.2
Anti rotational sutures	2	4.1

Intraoperative surgical complications were recorded in three cases. These complications were one misplaced implant, which was corrected during surgery, one loss of sterility, and one fissure line in the tibia that was discovered in the postoperative radiographs.

Short-term follow-up

The standard procedure at UDS is to perform a follow-up examination approximately four weeks after surgery. In this study, the number of clinical returns three months after surgery was recorded and within this time period, 46 out of 49 cases were examined by a veterinarian at UDS. One case visited another veterinary clinic for the follow-up examination, one case did not have a follow-up examination and one case is a missing value.

Postoperative complications

Medical data for the entire time period (0-365 days) post surgery could be acquired in 38 out of 49 cases. In nine cases data was missing in the medical records and the dog owners could not be reached even if repeated attempts were made to contact them. In the remaining two cases, data was missing because the dogs were deceased.

The total postoperative complication frequency within one year was 31.7% among the cases with available information (41 out of 49 cases). This means that 13 of 41 cases had at least one complication within one year after surgery. The number of cases with available information (n = 41) is higher than the number of cases with available data for the entire time period (n = 38). The difference is explained by the fact that in some of the cases with registered complications, data is missing for the latter part of the time period. Within one month there was 13 recorded complications, no missing values. Gastrointestinal symptoms were the most common complication within one month (n = 8). The gastrointestinal symptoms were suspected to be reactions to NSAIDs in most cases. Two dogs had delayed wound healing and one dog had a persistent patellar luxation. For the time period one month to one year post surgery there were two cases with complications, both implant related. Data were missing in 11 of the cases. The mortality rate one year after surgery was 4.7% (n = 2) among the cases where information about mortality was available (43 out of 49 cases). One of the dogs was euthanized because of recurrent patellar luxation and lameness after playing with another dog two months post surgery. The other dog was euthanized for reasons unrelated to patellar luxation. The complications are presented in Table 6.

Table 6: *Number of complications including mortality within one month, and one month to one year after surgery*

Complications	Within one month	Within one year
Gastrointestinal	8/49 (16.3 %)	-
Delayed wound healing	2/49 (4.1 %)	-
Persistent patellar luxation	1/49 (2.0 %)	-
Implant failure	-	2/41 (4.9 %)
Other	2/49 (4.1 %)	-
Mortality	-	2/43 (4.7 %)

There was a tendency towards fewer complications among dogs of the most common breeds but the difference was not significant. The dogs with complications were heavier with a mean body weight of 9.2 kg compared to the dogs without complication, which had a mean body weight of 6.8 kg. For each additional kilogram of body weight, the odds for getting a postoperative complication increased by 7 %. The difference was not significant. Sex, age and patellar grade did not affect the risk of complications. There was a trend towards more complications in the group with bilateral disease, odds ratio 3. The difference was however not significant.

The quality of life study

Description of cases and controls

Of the 45 dogs in the retrospective study, 38 dogs were included to participate the quality of live study and seven dogs were excluded. Five of the excluded dogs were deceased and two dogs were excluded due do surgical correction of MPL in the opposite stifle joint within the last year. Out of the 38 included dogs, nine dog owners could not be reached even if repeated attempts were made to contact them by email, telephone and/or text messages. In total, 29 answers were obtained in the case group. Two owners did not have an email address and one owner had technical problems with the online questionnaire and they were therefore interviewed by telephone. The remaining 26 owners answered the online questionnaire. The response rate in the quality of life study was 76.3% (29 out of 38).

In the control group, 54 dog-owners answered the questionnaire, but 15 answers were excluded because the criteria, as previously described, were not fulfilled. Excluding answers are can also be seen in Appendix 1. This gave a total number of 39 approved results. In the control group, the most common breed was the Pug, followed by mixed-breed, the Chihuahua, and the Poodle. The breed distribution is presented in Figure 5.

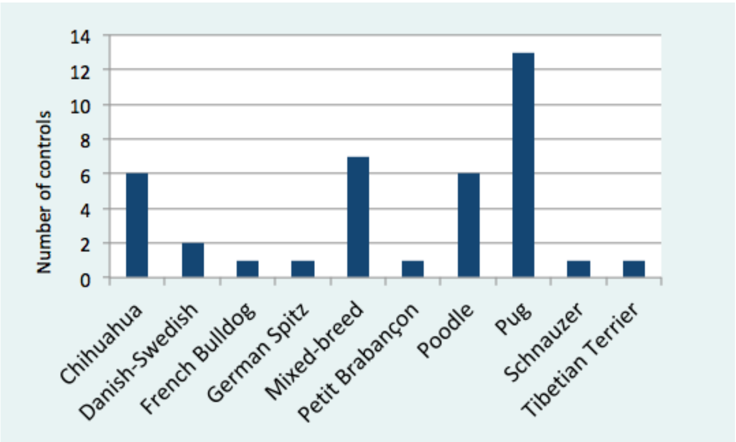

Figure 5: *Breed distribution in the control group.*

There was no significant difference in body weight or age between cases and controls. In the control group, the owners reported their dogs to have a body weight of below 6 kg (n = 13), 6 – 10.9 kg (n = 24), and 11 – 15.9 kg (n = 2). The mean body weight in the case group was 7,4 kg at the time of surgery. The mean age in the case group was 6.5 years (min 3, max 14.3) and the mean age in the control group was 6.6 years (min 3.4, max 11.9). The age distribution in both groups is visualized in Figure 6.

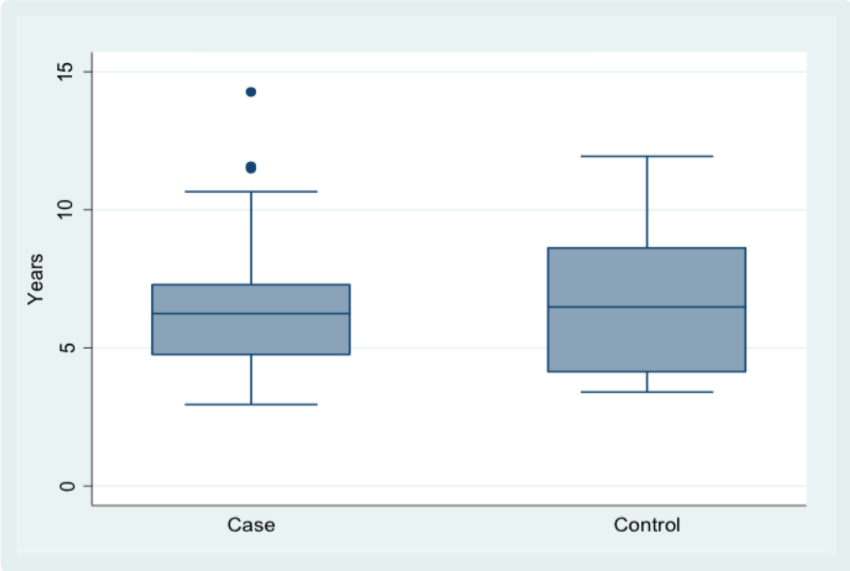

Figure 6: *Age distribution in the case group and in the control group.*

Results and scoring

Eight dog owners in the case group reported that their dog had been lame the last month. Six of the dogs had been lame in the surgically treated limb, one dog had been lame in both the surgically treated limb and another limb, one dog had been lame in another limb, and 21 dogs had not been lame at all. None of the dogs in the control group had been lame the last month, but this is a result of the excluding questions in the questionnaire. If an owner in the control group answered that their dog had any orthopedic disease, suffered from pain that caused a movement disorder, or had undergone orthopedic surgery, the questionnaire terminated. The case group was asked to evaluate if their dogs felt less discomfort in the surgically treated limb today than before the surgery. All dogs except one were more comfortable now than before the surgery, 17 owners answered that their dog was completely comfortable, 11 owners answered that their dog was less affected but still experienced some discomfort, and one owner answered that the discomfort was worse today than before the surgery.

The mean total score in the case group was 12.8 and the mean total score in the control group was 3.0. The difference was significant (p = 0,007) with a 95% confidence interval. As previously mentioned, is a low score beneficial for the dog, and a total score of 0.0 is the best possible outcome. In the case group, the highest score was 53 and the lowest score was 0. In the control group, the highest score was 11 and the lowest score was 0. There was no association between the total score and the time elapsed since surgery in the case group. This is visualized in Figure 7. The questions that gave the highest scores in the case group were “How often do you notice your dog’s joint problems” that gave a mean score of 1.1 “How often does your dog limp during moderate activities” that gave a mean score of 1.0 and “How often does your dog limp during mild activities” that gave a mean score of 0.9. The control group had a mean score of 0.0 in all these questions.

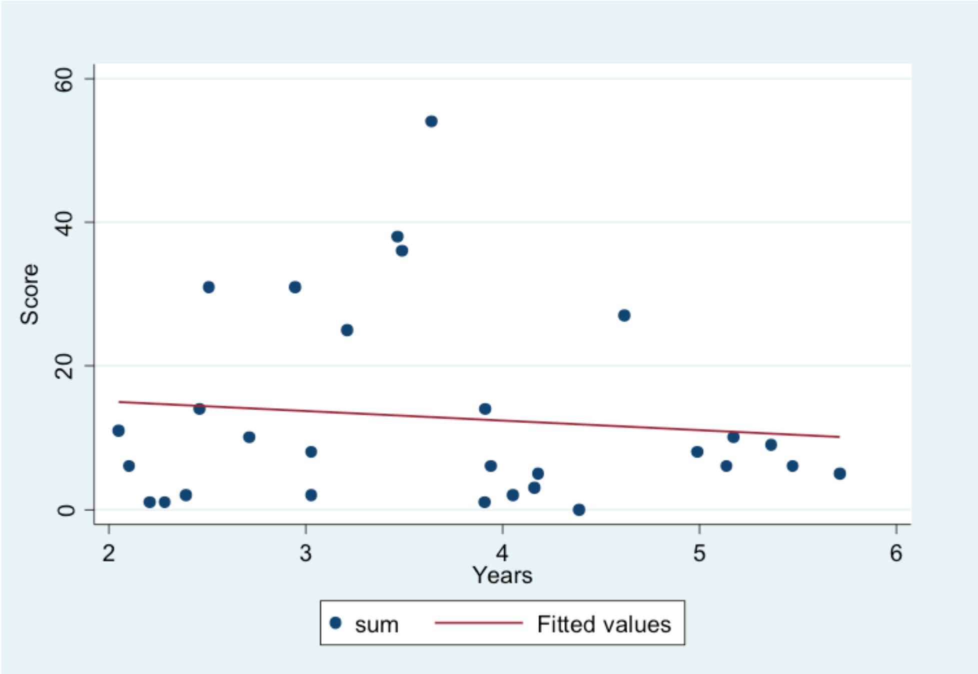

Figure 7: *Total scoring in the case group related to time since surgery. One dot represents one case.*

The questions that gave the lowest scores in the case group were questions regarding the ability to rise up and lay down, climb up and climb down, jump down, and the question "How would you rate your dog's quality of life". Regarding quality of life, 19/29 dogs were rated "very good" and 10/29 dogs rated as "good". There was a tendency that the dogs with the highest scores in the questions regarding lameness, i.e. the dogs with moderate to non-weight bearing lameness, had a "good" quality of life, and the dogs with low scores in the questions regarding lameness, i.e. the dogs with no or mild lameness, had a "very good" quality of life.

The questions with the highest scores in the control group were "How would you rate your dog's willingness to participate in play" that gave a mean score of 0,6, "How often does your dog vocalize" that gave a mean score of 0,4, and "How would you rate your dog's mood" that gave a mean score of 0,3. The case group had the mean scores 0,4, 0,6 and 0,4 in these questions.

DISCUSSION

The retrospective study

In this study, the most commonly affected pure breed dogs were the French Bulldog, the Pug, the Chihuahua and the Poodle. Previous studies have reported many different breeds to have an increased risk of MPL. The weaknesses of most studies are that the breed distribution in the population is unknown, and the majority of the studies have not defined which nomenclature that has been used when registering the breeds. The recognition of breeds differs among countries, making the breed distribution not completely comparable between studies. The breeds that are most frequently reported to be at increased risk are the Poodle, the Yorkshire Terrier, the Chihuahua and the Pomeranian (Priester, 1972; Hayes *et al.*, 1994; LaFond *et al.*, 2002; Vidoni *et al.*, 2005; Alam *et al.*, 2007; Cashmore *et al.*, 2014; Bosio *et al.*, 2017; OFA, 2017; SKK, 2017). The French Bulldog and the Pug have also been reported to have an increased risk of MPL, but not to the same extent (OFA, 2017; SKK, 2017). The high proportion of Pugs and French Bulldogs in this study may reflect the popularity of these breeds in the region, but statistics regarding breed distribution in the area have not been found. This study does not claim to present any numbers on prevalence in different breeds in Sweden. If the study had been performed in another region, the breed distribution would probably differ. In this study, the breed distribution was relevant when evaluating factors that may affect outcome after surgery, and to find a control group that corresponded to the case group.

It is interesting that only 8.3% of the Pomeranians born in Sweden year 2011-2015 have been evaluated for patellar luxation when 40.5% of the examined dogs had MPL, and only 1.4% of the Yorkshire Terriers have been evaluated even if 50% (n = 7) of the examined dogs had MPL. SKK has implemented a mandatory health program for patellar luxation for some of the breeds at risk, for example, the Chihuahua (SKK, 2017b). The Pomeranian and the Yorkshire Terrier are not included in this health program but patellar evaluation is still encouraged in all breeds at risk. There is room for improvement in the breeding strategies among several breeds in Sweden. To decrease the incidence of patellar luxation in the future, patellar luxation should be considered an important factor in the breeding programs.

The mean body weight in this study, at the time of surgery, was 7.4 kg. This finding corresponds with previous studies, which has reported an increased risk of MPL in small breed dogs (< 9 kg) (Priester 1972; Hayes *et al.,* 1994; Vidoni *et al.,* 2005; Bosio *et al.,* 2017). Some previous studies have reported that MPL may be increasing in large breed dogs, especially the Labrador Retriever (Arthurs & Langley-Hobbs 2006; Bound *et al.,* 2009). Both studies were conducted in the United Kingdom. In this study, there was no indication that the Labrador Retriever has an increased risk for MPL. There was no Labrador Retriever represented in this study even if the Labrador Retriever has been the most popular breed in Sweden every year 2009-2016 (SKK, 2010; SKK, 2012; SKK, 2014; SKK, 2016). Only five Labrador Retrievers born 2004-2017 have registered results from patellar evaluations in Sweden, all unaffected. This discrepancy might be explained by demographic differences among the breed.

In this study 55.6% of the cases had bilateral MPL and 44.4% of the cases had unilateral MPL. This result corresponds with previous findings, which have reported MPL being bilateral in 43-65% of the cases in studies including different dog breeds (Hayes *et al.,* 1994; Alam *et al.,* 2007; Bosio *et al.,* 2017).

Previous studies have defined complications as major or minor, where major complications are the complications that require revision surgery and minor complications are those that do not require surgery (Arthurs & Langley-Hobbs, 2006). In this study, we chose not to divide the complications into these two categories since the requirement of revision surgery does not necessarily mean that the complication has a major negative impact on the patient. For example, pins that cause discomfort and are removed after bone healing is complete is not a major problem for the patient's wellbeing. In many cases the pins may start to cause discomfort over time as the dog puts more weight on the leg, mobility improves and the dog uses its' leg more. On the other hand, there is no guarantee that the complication is a minor problem for the patient in the absence of revision surgery. For example, a muscle contracture is a major problem for the dog, but this was considered to be a minor complication in the study by Bosio *et al.* (2017) due to the definition of the two categories of complications.

The overall complication rate in this study was 31.7%. Previous studies have reported a complication rate of 18-24% (Arthurs & Langley-Hobbs 2006; Bosio *et al.,* 2017; Fullagar *et al.,* 2017; Perry *et al.,* 2017). In this study gastrointestinal disorder was the most common complication and accounted for 8/13 complications within one month. None of the studies above reported gastrointestinal disorders as complications. The increased complication rate in this study is explained by the high frequency of gastrointestinal symptoms. Excluding gastrointestinal symptoms, the complication rate in this study would be 15.5%.

This study had one known case of patellar reluxation (2.0%) and two known cases of implant failure (4.9%). Patellar reluxation and implant related complications have been described as the most common complications in several previous reports (Arthurs & Langley-Hobbs, 2006; Cashmore *et al.,* 2014; Gallegos *et al.,* 2016; Bosio *et al.,* 2017). The occurrence of patellar reluxation varies from 0% (Swiderski & Palmer, 2007; Brower *et al.,* 2017) to 48% (Willauer & Vasseur 1987). In this study, patellar reluxation was registered as a complication if the luxation was persistent or increased compared to the preoperative grade, but in the studies above all known cases of patellar reluxation was registered. The low frequency of patellar reluxation in this study is probably explained by the fact that milder patellar reluxations were not registered. The documentation of implant related problems differ in previous studies. Some studies classify implant related problems as severe or less severe and other studies only use one category (Gibbons *et al.,* 2006; Cashmore *et al.,* 2014). In this study, only the severe cases were reported. The fact that previous studies differ in study design, definitions, short time follow up and long time follow up makes it difficult to compare patellar reluxation and implant failure in this study with previous studies.

This study found a correlation between a heavier body weight and the occurrence of complications, but the finding was not significant. Two previous studies have reported this association (Arthurs & Langley-Hobbs, 2006; Bosio *et al.,* 2017) and another study found no such correlation (Cashmore *et al.,* 2014). The correlation in our study could be a coincidence, but it is possible that the association would be significant if more cases were included or if the definitions of the complications patellar reluxation and implant failure were altered. The tendency towards fewer complications among the most common breeds was not significant, but could still be relevant. The surgeons naturally have more experience in performing surgery on common breeds than on uncommon breeds. It is possible that this experience leads to a lower frequency of complications among the common breeds. More cases would be required to further investigate this correlation.

There was a trend towards more complications in the group with bilateral disease in this study (unilaterally or bilaterally surgically treated), but this finding was not significant. Previous reports have shown that the frequency of complications is similar between dogs with bilateral MPL treated with single-session bilateral surgery, staged bilateral surgery, or unilateral surgery (Clerfond *et al.,* 2014; Fullagar *et al.,* 2017). Whether the risk of complications is higher in dogs with bilateral MPL compared to in dogs with unilateral MPL has not been documented to the author's knowledge. A positive correlation was found between bilateral disease and the severity of MPL (see Figure 4) but this could not be proven. The correlation between bilateral disease and the severity of the luxation does not seem to have been previously reported. MPL is a developmental disease, that is presumed to be heritable, and the severity of the luxation is associated with the severity of the musculoskeletal abnormalities. Animals with a normal osteogenesis become relatively symmetrical in their conformation, consequently, a correlation between bilateral disease and patellar grade is highly plausible. In contrast to previous reports, no significant correlation between the severity of the luxation and the frequency of complications was found in this study (Cashmore *et al.*, 2014; Bosio *et al.*, 2017; Perry *et al.*, 2017). Further research is needed to investigate the correlations between bilateral disease and luxation grade, and bilateral disease and complication rate.

Age and sex did not affect the frequency of complications in this study. This result corresponds with results presented in previous studies (Willauer & Vasseur 1987; Arthurs & Langley-Hobbs, 2006; Cashmore *et al.,* 2014; Bosio *et al.*, 2017).

When analyzing if different variables such as body weight, bilateral disease, patellar grade, or surgical technique affect the occurrence of complications, maybe gastrointestinal complications should be excluded. It is unlikely that gastrointestinal disorders are affected by these variables, but since it was the most common complication in this study it could influence the results. However, it is possible that gastrointestinal complications could be affected by breed since some breeds tend to be more susceptible to gastrointestinal disorders.

The quality of life study

The case group and the control group were equivalent regarding age and weight. For the case group, the weight is specified at the time of surgery but there is no present weight recorded. The owners of the control dogs estimated their dog's weight and chose a weight range in the questionnaire, see Appendix 1. The method to measure weight and the time for measurement diverge between the groups, but the comparison between weights is sufficient for the purpose of this study. The control group included more Pugs and fewer French Bulldogs than the case group but these breeds are quite similar regarding composition and health and should be comparable. The case group also had a wider breed distribution than the control group.

All dog owners in the case group except one rated their dogs comfort to be better today than before the surgery, but 37.9% (11/29) of the dogs still experienced some discomfort which is reflected in the scoring. One dog was worse today than before the surgery, this was also the dog with the highest scoring (53). The reason why some dogs still experienced discomfort was not found in this study. It is possible that the discomfort could be related to the progression of degenerative joint disease in the stifle joint, but since the dogs did not have a long-term follow-up examination this is just a hypothesis.

There was a significant difference between mean scores in the case group and the control group, indicating that even after a successful surgical correction of MPL the expectation cannot be to regain equal mobility and function in the stifle joint compared to a dog without any orthopedic disorder. However, even if the mean score in the case group was 12.8 there were only nine dogs that scored higher than 12, the remaining 20 dogs had the score 11 or lower, and the median score was seven. Eight dogs scored three or lower which is the same score as the mean score in the control group. This means that in 27.6% of the cases, the long-term result after surgery was comparable with the results of dogs without any orthopedic disease. Even if there was a great variation of the scoring within the case group we did not find any variable, for example patellar grade that could explain this variation. It is possible that an association could be made with a larger number of cases, or the variation is related to a variable not included in this study. To identify variables that might explain the variation and to find the reason for the orthopedic problem, an orthopedic examination including a radiographic examination has to be performed.

The questions that generated the highest scores in the case group were all related to lameness during activity. In the control group, the questions related to lameness got the lowest scores, but a mild lameness may be difficult to discover for the owners. Questions relating to stiffness and function also yielded difference in scoring between the case group and the control group. However, the difference was lesser than in the questions regarding lameness.

The questions regarding the dogs' mood, willingness to play and vocalization generated similar scores in the case group and the control group. The dogs' willingness to participate in play was actually greater in the case group than in the control group. These questions are more difficult to interpret and they are not directly associated with orthopedic diseases as the questions regarding stiffness, lameness or function. Pain can have a negative influence on a dog's mood, but other aspects, for example, breed, personality, mental and physical training, among other things, can also affect mood and behaviour. A dog's willingness to participate in play differs among individuals and breeds even if a comparison would be made between healthy dogs only. Of course, pain can have a negative effect on the willingness to play but the willingness to play is probably related to both the severity of the pain and the dog's intrinsic playfulness. Vocalization (whining or crying) is increased by pain, but it can also be increased by stress and it is used to express overall dissatisfaction. The tendency to vocalize is also related to the dog's personality. Recently, vocalization has been removed from the Helsinki pain score since this has been shown to be too unreliable as a score of quality of life and pain (Hielm-Björkman, A., University of Helsinki, lecture at SLU, 2012-11-07).

The dogs' quality of life was considered to be good or very good in all cases and controls. Some of the dogs in the case groups got scores from two to four in each question regarding lameness but none of the dogs had a score higher than one regarding the quality of life. This result could indicate that the dogs actually have a good quality of life even if they experience some degree of lameness, or that dog owners underestimate the impact of lameness on life quality. The meaning of the expression quality of life is subjective and people may include different aspects of life in the evaluation. Absence or presence of pain, general health, the ability to express natural behaviour, the mental state, and mental and physical stimulation are different aspects that can affect the quality of life. A dog with moderate lameness may still have a good quality of life if other aspects of life enhance the life quality. It is also possible that some dog owners have rated their dog's quality of life from the dog's present situation, believing that the dog has the best quality of life that is possible while being lame. The baseline for a good quality of life could also be lower for a dog that has been suffering from some degree of lameness the majority of it's life, compared to a dog that has been healthy its entire life. Since some of the questions can be interpreted in different ways, the most accurate way to evaluate the quality of life is probably to look at the total scoring of the questionnaire.

Limitations of this study

The retrospective design of this study limits the accuracy of data to rely on the accuracy of the medical records. There was no set protocol for examination of the dogs pre- and post surgery. The selected surgical techniques differ among the cases and depend on which deformities that caused the luxation. The variance in both anatomic deformities and surgical methods makes it complicated to analyze factors that can affect the risk of complications, outcome after surgery, and quality of life. Not all medical records included data one year post surgery, in these cases information was obtained from the dog owners. The numerical grade of the patellar luxation was not always expressed in the medical records and in these cases the grade was determined from the written description. Nine dog owners included in the quality of life study did not answer the questionnaire. The answers in the questionnaire reflect the owners' perception of their dogs, no examination of the dogs have been made at the present time. There is no way to confirm that the owners have read the questions thoroughly and answered the questions with accuracy. The quality of the answers could also be affected by the presence or absence of an interviewer (Saris & Gallhofer, 2014). Even if the intention was that all respondents should have answered the questionnaire in Google Forms, three of the interviews in the case group were performed by telephone. The control group was not randomly selected. A veterinarian has not examined the dogs in the control group, thus the accuracy of information about the control group relies on facts stated by the dog owners.

CONCLUSIONS

The comfort in the stifle joint generally improved after surgical correction of the patellar luxation. The dogs' mood, willingness to participate in play, vocalization and quality of life as assessed by the owner seems to be comparable between surgically treated dogs and dogs without any orthopedic disorder. Lameness was the most common problem for the surgically treated dogs according to the owners. Mobility and function were also affected but to a lower extent. Even if many surgically treated dogs had a good or decent score on the questionnaire, the result was significantly higher in the case group than in the control group. The expectations with corrective surgery for MPL should be adapted to this finding. There was a great variation in total scoring among the surgically treated dogs, but the reason for this variation could not be concluded. The variety could not be explained by patellar grade or occurrence of complications. Further research with more cases and analyses is needed to study the variables that affect the long-term outcome, discomfort and lameness in surgically treated dogs. In this study, there was an association between bilateral disease and a higher complication rate, but the finding was not significant. Further research is needed to investigate this association.

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APPENDIX 1

Quality of life questionnaire

E-mail address

Medical record number (case group only)

Name

Date of birth

Breed

Sex

- Male
- Castrated male
- Female
- Castrated/sterilised female

Body weight (control group only)

- 0 – 5,9 kg
- 6 – 10,9 kg
- 11 – 15,9 kg
- > 15 kg (excluding answer)
- Don't know

Is your dog insured?

- Yes
- No
- Don't know

Is the dog currently under your care?

- Yes
- No, under someone else's care (excluding answer in the control group)
- No, euthanized due to patellar disease (excluding answer)
- No, euthanized due to another orthopedic disease (excluding answer)
- No, euthanized/deceased for another reason (excluding answer)

Has the dog undergone corrective surgery for patellar luxation at another clinic than the University Animal Hospital? (case group only)

- No
- Yes, additional surgery in the same stifle
- Yes, surgery in the opposite stifle
- Yes, additional surgery in the same stifle and the opposite stifle
- Don't know

What is the name of the clinic? (case group only)

Do you approve that we acquire the medical records from this clinic, since it may be relevant for this study? (case group only)

- Yes
- No
- I want more information before I answer the question, please contact me in advance

Does your dog have other orthopedic diseases that you are aware of? (for example hip dysplasia, elbow dysplasia, spinal disc herniation, fractures, ligament injuries) (case group only)

- Yes
- No

Please describe the disease and which joint or limb that is affected. Does the dog have any symptoms from the disease? (case group only)

Has your dog undergone corrective surgery for patellar luxation? (control group only)

- Yes (excluding answer)
- No
- Don't know

Has your dog undergone surgery for any other orthopedic disease? (control group only)

- Yes (excluding answer)
- No
- Don't know

Does your dog have any orthopedic diseases that you are aware of or does your dog suffer from pain that causes any movement disorder? (for example hip dysplasia, elbow dysplasia, spinal disc herniation, fractures, ligament injuries) (control group only)

- No disease, pain or movement disorder, that I am aware of
- No disease or pain that I am aware of, but my dog has a movement disorder
- Yes, orthopedic disease (excluding answer)
- Yes, pain that causes a movement disorder (excluding answer)
- Yes, in the kneecaps

Is your dog diagnosed with patellar luxation? (control group only)

- Not what I am aware of
- Yes, grade 1 / mild luxation. The dog does not have any symptoms
- Yes, grade 1 / mild luxation. The dog has a mild movement disorder
- Yes, grade 2 / moderate luxation or worse (excluding answer)
- The veterinarian said something about loose kneecaps or patellar luxation but I don't know the severity
- Don't know

Is the dog on any medication? (supplements not included)

- Yes
- No

- Sometimes/when needed

What is the name of the medication/medications?

For how long time has the dog been on the medication?

What is the reason for the medication?

- Patellar luxation
- Another orthopedic disease
- Other systemic diseases (for example diabetes, dermatological disorders, gastrointestinal disorders)

The following questions concern the dog's function the last month. We wish that you answer the questions with a focus on the surgically treated limb/limbs. If the dog has symptoms from additional injuries or diseases, please try to evaluate which symptoms that relate to the surgically treated stifle/stifles.

In the past month, has your dog been lame?

- Yes, in the surgically treated limb/limbs
- Yes, in another limb/limbs (not surgically treated)
- Yes, both in the surgically treated limb and another limb
- No, the dog has not shown any signs of lameness
- Don't know

Do you experience that your dog is less affected by the surgically treated limb today than before the stifle surgery? (case group only)

- Yes, the dog is completely comfortable
- Yes, the dog is less affected but still experience some discomfort
- No difference
- Worse
- Don´t know
- Not applicable (the dog suffers from a new injury in the same limb)

Questions regarding stiffness

How severe is your dog's stiffness after wakening up in the morning

0 No stiffness

1 Mild stiffness

2 Moderate stiffness (for example visible lameness but ability to walk and run)

3 Severe stiffness (difficulty to walk)

4 Non-weight bearing on the surgically treated limb

6 Don't know

Later in the day, how severe is your dog's stiffness after lying down for at least 15 minutes?

0 No stiffness

1 Mild stiffness

2 Moderate stiffness (for example visible lameness but ability to walk and run)

3 Severe stiffness (difficulty to walk)

4 Non-weight bearing on the surgically treated limb

6 Don’t know

Later in the day, how much problem does your dog have rising to standing after lying down for at least 15 minutes?

0 No problems

1 Mild problems

2 Moderate problems

3 Severe problems

4 Can’t rise up without help

6 Don’t know

How difficult is it for your dog to lay down?

0 No problems

1 Mild problems

2 Moderate problems

3 Severe problems

4 Can’t lay down without help

6 Don’t know

Questions regarding function

In general, over the last month, how much difficulty has your dog had with his or her knees?

0 No problems

1 Mild problems

2 Moderate problems

3 Severe problems

4 Extreme problems

6 Don’t know

How difficult is it for your dog to jump up? (for example into the car or onto the sofa)

0 No problems

1 Some hesitation at times

2 Always hesitates but is able to jump up by him/her self

3 Always hesitates and needs assistance

4 Not able to jump at all

5 Not applicable, the dog is not allowed to jump (for example under convalescence)

6 Don’t know

How difficult is it for your dog to jump down? (for example from the car or from the sofa)

0 No problems

1 Some hesitation at times

2 Always hesitates but is able to jump down by him/her self

3 Always hesitates and needs assistance

4 Not able to jump at all

5 Not applicable, the dog is not allowed to jump (for example under convalescence)

6 Don’t know

How difficult is it for your dog to climb up? (for example up the stairs or a ramp)

0 No problems

1 Some hesitation at times

2 Always hesitates but is able to climb up by him/her self

3 Always hesitates and needs assistance

4 Not able to climb at all

5 Not applicable, the dog is not allowed to climb (for example under convalescence)

6 Don’t know

How difficult is it for your dog to climb down? (for example down the stairs or a ramp)

0 No problems

1 Some hesitation at times

2 Always hesitates but is able to climb down by him/her self

3 Always hesitates and needs assistance

4 Not able to climb at all

5 Not applicable, the dog is not allowed to climb (for example under convalescence)

6 Don’t know

Questions regarding lameness

How often does your dog limp during mild activities such as short walks?

0 Never

1 Rarely

2 Occasionally

3 Frequently but not every time

4 Every time

5 Not applicable, the dog is not allowed to walk (for example under convalescence)

6 Don’t know

How severe is your dog’s lameness during mild activities such as short walks?

0 No lameness

1 Mild lameness (for example of short duration)

2 Moderate (limping during the entire walk)

3 Severe lameness (uses all four limbs but have severe problems with the surgically treated limb)

4 Non-weight bearing lameness

5 Don't know

How often does your dog limp during moderate activities such as long walks including trot and gallop?

0 Never

1 Rarely

2 Occasionally

3 Frequently but not every time

4 Every time

5 Not applicable, the dog is not allowed to walk (for example under convalescence)

6 Don't know

How severe is your dog's lameness during moderate activities such as long walks including trot and gallop?

0 No lameness

1 Mild lameness (for example of short duration)

2 Moderate (limping during the entire walk)

3 Severe lameness (uses all four limbs but have severe problems with the surgically treated limb)

4 Non-weight bearing lameness

5 Don't know

How often does your dog limp the day after moderate activities?

0 Never

1 Rarely

2 Occasionally

3 Frequently but not every time

4 Every time

5 Not applicable, the dog is not allowed to walk (for example under convalescence)

6 Don't know

How often does your dog show signs of increased pain or stiffness the day after moderate activities?

0 Never

1 Rarely

2 Occasionally

3 Frequently but not every time

4 Every time

5 Not applicable, the dog is not allowed to walk (for example under convalescence)

6 Don't know

Questions regarding quality of life

How often do you notice your dog’s joint problems?

0 Never

1 Rarely

2 Occasionally

3 Frequently

4 Every day

5 Not applicable, the dog is suffering from another injury or disease

6 Don’t know

How would you rate your dog’s mood?

0 Very alert

1 Alert

2 Neither alert nor indifferent

3 Indifferent

4 Very indifferent

5 Hard to tell since the dog suffers from another injury or disease which may affect it’s mood

6 Don’t know

How would you rate your dog’s willingness to participate in play?

0 Very willing

1 Willing

2 Reluctant

3 Very reluctant

4 Never plays

5 Not applicable, the dog is not allowed to play (for example under convalescence)

6 Don’t know

How often does your dog vocalize? (whining or crying out)

0 Never

1 Rarely

2 Occasionally

3 Often

4 Very often

6 Don’t know

How would you rate your dog’s quality of life?

0 Very good

1 Good

2 As many good as bad days

3 Fair, the dog has good moments from time to time

4 Poor, reduced quality of life most of the time

5 Hard to tell since the dog currently suffers from another injury or disease

6 Don’t know

What is your level of concern that your dog is generally slowing down?

0 None

1 Mild, I rarely think about it

2 Moderate, I think about it every week

3 Severe, I often think about it

4 Extreme, I worry every day

5 Hard to tell since the dog currently suffers from another injury or disease

6 Don’t know

What is your level of concern that your dog’s joint problems will shorten his or her life?

0 None

1 Mild, I rarely think about it

2 Moderate, I think about it every week

3 Severe, I often think about it

4 Extreme, I worry every day

5 Hard to tell since the dog currently suffers from another injury or disease

6 Don’t know