Chapter 8

Patellar Luxation in Small Animals

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Abstract

This study describes lesions that occur in the stifle joints of dogs with patellar luxation. These lesions are associated with the animal's age, body weight and degree of luxation. It also reports on the rate of re-dislocation. The patellar lesions found include articular cartilage erosion, subchondral bone exposure, a flattened or concave patellar surface and enthesophytes. Extrapatellar lesions included synovitis, osteophytes, blunting of the trochlear groove, an absent trochlea, erosion of the condylar margins, capsule thickening, a long digital extensor tendon injury, "joint mice," flap formation, cranial cruciate ligament rupture and meniscal prolapse. Such lesions were frequently found in animals with grade II or III luxation that were aged 24 months or older; they were more severe in dogs weighing more than 15 kg. Patellar luxation causes changes that favour articular degeneration and should be treated surgically. Conservative treatment relieves pain but does not address tissue alterations.

Keywords: luxation, patella, dogs, lesions, joint

1. Introduction

Patellar luxation is a frequent occurrence in dogs and thus represents a common finding in everyday veterinary trauma and orthopaedic practice [1]. However, early treatment is not considered important. Clinical signs vary with the severity of luxation, and in some cases, the diagnosis is made during routine physical examination. The luxation may be present at birth, and in these cases are usually grades III and IV associated with severe skeletal deformities

with functional disability (**Figure 1A, B**). In puppies, the surgical correction must be performed between 1 and 3 months of age, and not later than 3 months [2]. At this age, the skeletal deformities can be reversed after alignment of the limb. Patellar luxation may occur at birth, during growth or at a later stage. The pathophysiology of congenital luxation remains a topic of discussion [3–5]; a consequence of complex skeletal abnormalities that alter the limb alignment is considered [5]. The condition may be unilateral or bilateral and can be asymptomatic, and most cases are medial [3, 5]. Occasionally, the luxation can occur in both directions in the same joint [3], which is a surgical challenge. It is possible to find medial patellar luxation in one joint and lateral luxation in another joint in the same dog. Some cases exhibit patellar subluxation. Although much less frequently than in dogs, patellar dislocation also occurs in cats [3].

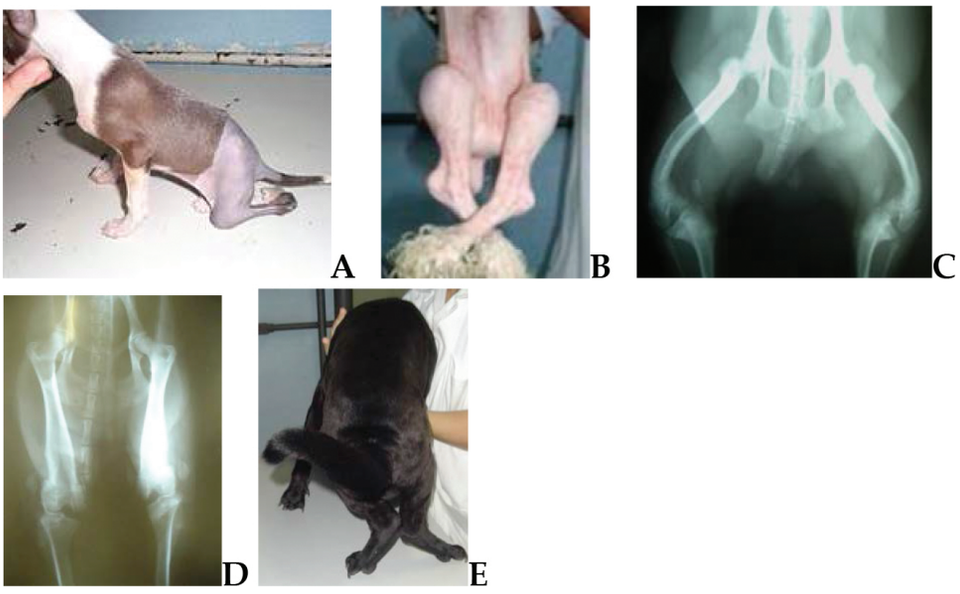

Figure 1. (A) Abnormal position associated with bilateral grade IV medial patellar luxation in puppies 60 and (B) 90 days old; (C) ventrodorsal radiograph, showing bilateral medial luxation of the patella, and angular deformities in a 90-day-old poodle; (D) ventrodorsal radiograph, showing bilateral lateral luxation of the patella in a 9-month-old dog breed Sharpei; (E) abnormal stance associated with bilateral grade IV lateral patellar.

The incidence of severe articular lesions found during routine surgeries in small-, medium- or large-breed dogs presenting with patellar luxation is high. In some cases, the patella injury is so serious that correction is not possible or prudent. In these instances, a better treatment option may be prosthetic replacement. Patellectomy is suggested as a treatment alternative in some severe cases [5, 6], but the removal of the patella does not correct the skeletal changes [6], calling this therapeutic option into question.

According to the literature [5], surgery might not be necessary in cases without clinical manifestations or when lameness is mild; however, even under such circumstances, the joint damage is irreversible.

Patellar luxation is a degenerative condition, and surgical treatment should be performed as early as possible, while clinical signs are mild or even before they appear. The aims of this

study were to perform a retrospective survey of the lesions found in the stifle joints of dogs with patellar luxation, to investigate the associations between these lesions and the animal's age, body weight and degree of luxation and to estimate the incidence of re-luxation after surgical treatment.

2. Anatomy and etiopathogenesis

The patella is an oval-shaped sesamoid bone that is located in the quadriceps tendon [7, 8] and connected to the fabella by a thin band of loose connective tissue known as the medial and lateral patellofemoral ligament [3, 7, 8]. The tendon located between the distal aspect of the patella and the tuberosity of the tibia is known as the patellar ligament [3]. The patella acts as a lever arm favouring the extension of the quadriceps [3], and the patellofemoral joint increases the mechanical efficiency of the quadriceps mechanism [8]. The correct alignment of the quadriceps femoris, patella, trochlea, patellar ligament and tibial tuberosity prevents patellar luxation or subluxation [8]. An adequate supply of articular cartilage depends on a normal joint between femoral trochlea and patella. Patellar luxation causes articular cartilage degeneration [3].

The pathogenesis of developmental patellar luxation remains speculative and controversial [3, 5, 9]. Based on the thesis by Putnam [10], abnormal femoral and neck angles of inclination and anteversion are proposed to influence development and eventual malformation of the pelvic limb. However, this has not been proven [11].

The III and IV degrees of luxation are associated with severe angular and rotational deformities of the femur and tibia [8], which are more pronounced in medial luxation; the limb has an S-shaped conformation (**Figure 1B, C**). Some cases are difficult to treat, with poorer prognosis. Corrective osteotomy must be considered in these cases to restore the normal alignment of the quadriceps complex [5, 6]. It is sometimes necessary to also remove up to 1.0 cm of bone extension to return the patella to the femoral trochlea. In these cases, patella tibial tuberosity alignment is achieved but paw rotation remains. Therefore, early intervention should be considered in cases of patellar luxation independent of the existence of clinical signs.

Clinical evidence shows that intermittent patellar luxation, contrary to the logical assumption, produces varying degrees of injury to the articular surfaces of the patella and the femoral condyle, causing degeneration of articular cartilage. This may also result in a flattening of the femoral condyle and consequently facilitate dislocation [8]. The position of the patella relative to the femoral trochlea, more proximal, is considered by some authors [8, 13, 14] to be an important factor in canine patellar luxation.

Although seldom discussed in the literature, subluxation also occurs and is observed in clinical practice. The affected dogs are typically adults presenting with pain and lameness due to the wear on the patella [8]. This condition is difficult to diagnose, especially in heavy English Bulldogs; a careful physical examination is necessary. Other findings, including cruciate ligament rupture and even the presence of intra-articular loose bodies and flap formation, can be seen in cases of chronic patellar dislocation.

Medial patellar dislocation is responsible for approximately 80% [5] of cases, with bilateral involvement in up to 50–65% [5, 14]. Lameness is one of the presenting clinical signs; however, it is subjective; lameness is seen in other conditions that affect the hind limb, which should be included in the differential diagnosis [6, 15]. Medial luxation is considered characteristic of small breeds, but it has been reported with increasing frequency in large and giant breeds [5].

Although many dogs present at 6–12 months of age, some animals with mild lameness present later, with rupture of the cranial cruciate ligament or pain caused by osteoarthritis [8]. Often, the patellar luxation is not considered to be an important joint disorder until it becomes severe. In puppies, the situation is even more critical. Post-operative studies show that it is possible to correct the limb deformities and achieve complete reversal of skeletal changes if the surgery is performed before 60 days of age [2].

Lateral luxation also occurs in small dogs; the skeletal deformities are the reverse of those seen with medial luxation (**Figure 1D, E**), demonstrating an increased angle of anteversion, coxa valga, medial torsion of the distal femur, lateral condylar dysplasia, lateral rotation of the tibia and external rotation of the paw [16, 17]. The articular cartilage injuries in both types of luxation result in osteoarthritis [16, 18], which is usually mild-to-moderate and unrelated to the degree of luxation or lameness [19]. Lateral luxation of the patella may cause injury at the origin of the long digital extensor tendon, leading to rupture of the tendon in severe cases.

3. Clinical signs

The clinical signs of patellar luxation vary according to the degree of deformity, duration of the condition, unilateral or bilateral stifle involvement [8] and the age of onset. Degree III or IV luxation in puppies prevents ambulation (**Figure 1A, B**) and causes the characteristic changes of Genu varum or a "bow-legged" conformation in some cases of medial patellar luxation (**Figure 2A, B**). In lateral patellar luxation, the associated abnormal anatomic features are reversed. These dogs may have a knock-kneed appearance when affected bilaterally (**Figure 2C, D**).

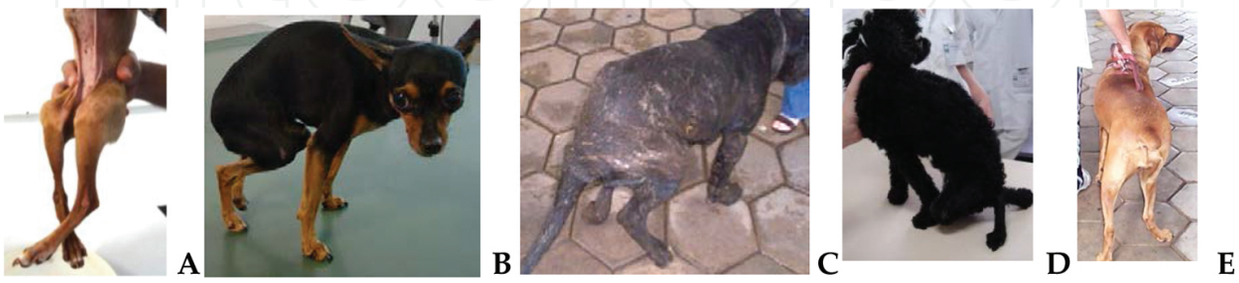

Figure 2. Abnormal stance associated with: bilateral grade IV medial patellar luxation in a (A) 5- and (B) 3-year-old pinscher; lateral patellar luxation in a 6-month-old Fila Brasileiro (C) and (D) 3-year-old poodle; (E) unilateral grade III lateral luxation in a crossbreed 4-year-old dog.

In clinical practice, four classes of patients [5] are encountered: neonates and older puppies with grade III or IV luxation and inability to walk (**Figure 1A**), young or mature dogs with grade II to III luxation and mild clinical signs for a long period of time until presenting when the clinical condition worsens, older animals with grade I or II luxation and sudden claudication due to the cruciate cranial ligament rupture or degenerative joint disease pain and asymptomatic dogs.

Clinical signs vary from animal to animal and may be intermittent or continuous. Associated joint damage and overweight may worsen the clinical signs. The physical examination should be performed carefully; gentle palpation without causing pain is the goal, considering the difficulty of identifying the patella in toy and miniature animals as well as in dogs with severe deformities. In general, dogs with lateral luxation have more ambulation problems than those with medial luxations [5].

The physical examination should consider aspects such as instability in both directions, crepitus, degree of tibial rotation, limb deformity, inability to reduce the patella, location of the reduced patella within the trochlea, inability to stand the limb to a normal standing angle and presence/absence of cruciate ligament rupture. This information is necessary for surgical planning [5].

Patellar dislocation is classified into four grades [20] to facilitate the diagnosis and plan the method of surgical repair:

Grade I. A dog with grade I patellar luxation rarely shows lameness and carries the limb occasionally. The patella can be manually luxated when the stifle is extended, but it returns to the trochlea when released. No crepitation is apparent. Internal rotation of the tibia and displacement of tibial tuberosity are minimal.

Grade II. Luxation occurs more frequently than in grade I. Lameness signs are usually intermittent and mild. The patella moves easily, especially when the foot is rotated, while the patella is pushed. The proximal tibial tuberosity may be rotated up to 30° with medial luxations and less with lateral luxations. Many grade II patients live reasonably well for many years, but the injuries from constant friction between the patella and femoral condyle result in crepitation and increasing discomfort [5].

Grade III. The patella is permanently luxated, with torsion of the tibia and deviation of the tibial crest between 30° and 60°. It can be reduced, but luxation recurs immediately. The trochlea is very shallow or even flattened. Although they have permanent luxation, many animals use the limb with the stifle held in a semi-flexed position.

Grade IV. The patella is permanently luxated, and it is not possible to manually reposition it in the trochlea. It lies just above the medial condyle (if a medial luxation) (**Figure 1C**). Angular and rotational deformity of the femur and tibia are generally marked, and the tibial crest is displaced 60°–90°. The trochlea is shallow, absent or even convex. The limb may be carried if unilateral, or the animal moves in a crouched position, with the limbs partially flexed or carried in toy animals (**Figure 2B**).

4. Radiography

The diagnosis of patellar luxation is clinical, but radiography may help to confirm the diagnosis, showing the luxated patella in more severe cases, and can demonstrate any bony deformities that are present [6]. Mediolateral and craniocaudal radiographs enable assessment of femoral and tibial deformities (**Figure 3A, B**). Tangential views of the flexed stifle enable assessment of the femoral trochlea and its depth (**Figure 3C**). Radiographs can also delineate the morphological changes of the patella and trochlea, demonstrate secondary osteoarthritis [6, 8] and allow the prognosis of limb function.

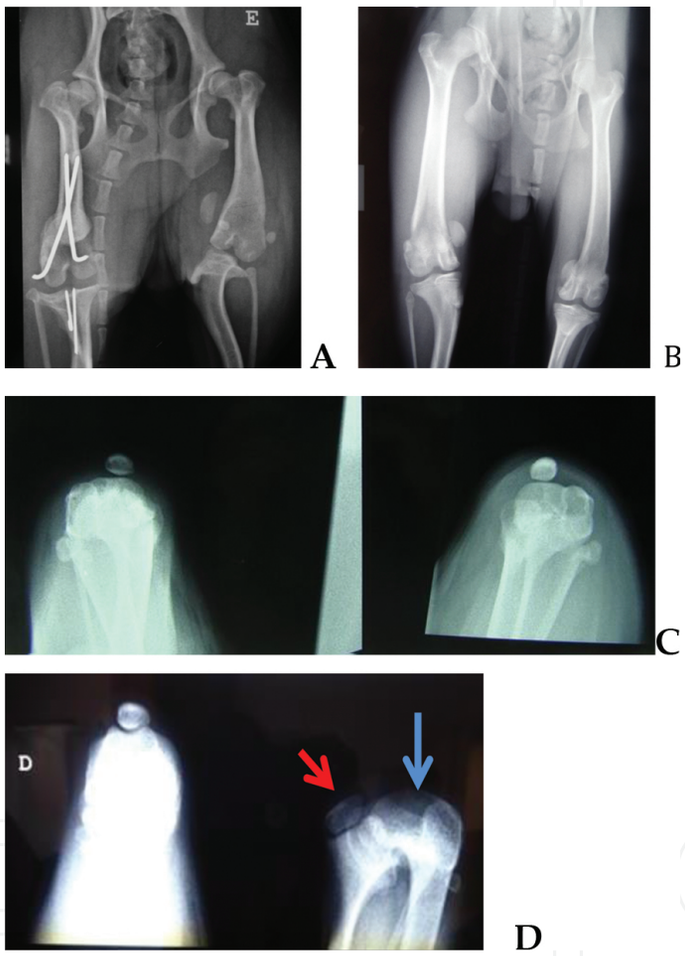

Figure 3. Anteroposterior radiograph of the limbs of a dog, showing: (A) medial luxation grade IV in a 16-month-old Pekinese (left); (B) bilateral medial luxation grade III; (C) tangential view of flexed stifle showing an absent trochlea; (D) tangential view showing shallow trochlea (blue arrow), and ectopic patella in a new trochlea (red arrow).

5. Treatment

Surgical management of patellar luxation in asymptomatic small-breed dogs is controversial and is not considered necessary. However, surgery is recommended early in young puppies

(3–4 months) prior to irreparable contracture and in medium to large breeds prior to erosion and trochlea deformity [5]. The goal of surgical treatment is to realign the extensor apparatus to restore normal stifle biomechanics and stabilize the femoropatellar joint. Surgical procedures to stabilize patellar luxation can be divided into soft tissue reconstruction and bone reconstruction [5]. The surgical techniques include deepening of the femoral trochlea, tibial tuberosity transposition, medial soft tissue release and lateral soft tissue tightening. Other procedures, such as transplantation of the origin of the rectus femoris muscle and corrective osteotomy, can be necessary in grade III or IV patellar luxation [6, 8]. It is sometimes necessary to shorten the femur to reduce the luxation. The presence of patellar injuries does not necessarily indicate a surgical contraindication. Healing may occur, and the realignment of the quadriceps shows favourable results even in the presence of osteoarthritis. Patellectomy is rarely necessary, does not produce benefits and does not correct the alignment of the quadriceps complex [6].

6. Patellar luxations in cats

A slight increase in the occurrence of patellar luxation has been observed in cats; however, it is far less common than in dogs [21]; it has been reported in breeds such as the Abyssinian, Devon Rex, Siamese, domestic shorthair cats [22–24], and non-pedigree cats [21, 25]. Some authors report a relationship with hip dysplasia [8], but this remains controversial. As in the dog, medial patellar luxation is the most common and may be either unilateral or bilateral. Most affected cats are usually relatively young at the time of presentation [25]. Some anatomical considerations are necessary to prevent misdiagnosis. The patella in the cat is relatively wider and has more physiological laxity than in dogs. It can be manually moved onto the trochlear ridge of the femoral condyles in many normal cats. Therefore, the grading system developed for dogs should be used with caution [26].

Considering these peculiarities, Voss et al. [27] suggested the following grading system for patellar luxation in cats:

Grade A. Patella can be completely luxated with digital pressure, but immediately returns into position after pressure is released.

Grade B. Patella can be completely luxated with digital pressure and remains temporarily luxated after the pressure is released.

Grade C. Patella luxates when the tibia is internally rotated without exerting direct digital pressure.

Grade D. Patella is temporarily or permanently luxated without any manipulation.

Anatomical changes are similar to those in the dog, including a shallow trochlear groove and medial displacement of the tibial tuberosity. Severe conformational changes are rarely observed, and secondary osteoarthritis is generally absent or mild [28]. It may be associated with the age at diagnosis of patellar luxation because older cats may have severe degenerative

changes in their stifle joints [28]. Erosions in the patella and on the condylar ridge may be seen as in dogs. Although surgical treatment is suggested when the luxation results in lameness [21], it should be considered early, aiming to align the quadriceps and prevent degenerative changes.

Congenital bilateral patellar aplasia has been described in two Siamese cat littermates [29].

7. Materials and methods

This was a retrospective study that assessed the clinical surgical records of dogs treated for patellar luxation from January 2005 to January 2016 at the Veterinary Hospital, Federal University of Minas Gerais (FUMG) in Brazil. Data describing age, body weight and the degree of patellar luxation at admission were collected for each animal. The animals were then categorized based on body weight (≤5, 5–15 and ≥15 kg), age (<12, 12–24 and >24 months) and degree of luxation according to Putnam's [10] classification as adapted by Singleton [19]. In addition, data relative to the intraoperative period were recorded; these included the presence of stifle joint damage, classified as patellar or extrapatellar lesions and the frequency of post-operative re-luxation. The associations between patellar or extra-patellar lesions and the animal's age, body weight and degree of luxation were investigated. Patellar lesions included the presence of cartilage erosion, the extent of the erosion (one-fourth, one-half or the full patellar articular surface), the morphology of the patella (concave or flat), the exposure of subchondral bone and the presence of enthesophytes. Extra-patellar lesions included the presence of erosion and subchondral bone exposure in the medial or lateral femoral condyles, the presence of osteophytes, synovitis, capsular thickening or shallowing of the trochlea, an absent or convex trochlear groove, cruciate ligament rupture and injury of the long digital extensor tendon and the menisci.

The frequency of lesions in the stifle joint was subjected to descriptive analysis, and the rate of patellar re-luxation was assessed using the chi-square test. The significance level was set at $P < 0.05$.

This retrospective study also included the clinical records of eight cats (13 joints) treated for patellar luxation. Data describing age, body weight and the degree of patellar luxation at admission were collected for each animal.

8. Results

A total of 280 luxated joints from 202 dogs were assessed; 244 were in medial luxation, whereas 36 were in lateral luxation. Sixteen (5.7%) were classified as grade I, 118 (42.1%) as grade II, 57 (20.4%) as grade III and 89 (31.8%) as grade IV.

The patellar lesions identified included cartilage erosion of one-fourth (15.0%), one-half (11.8%) or all (1.8%) of the patella, exposure of subchondral bone (4.3%), a flattened or concave

patellar surface (15.0%) (**Figure 4**), the presence of enthesophytes (12.1%), cartilage flap at the edge of femoral condyle, joint mice and lesions caused by the patella rubbing on the long digital extensor tendon (**Figure 5**). **Tables 1** and **2** show the lesions according to degree of dislocation, weight and age.

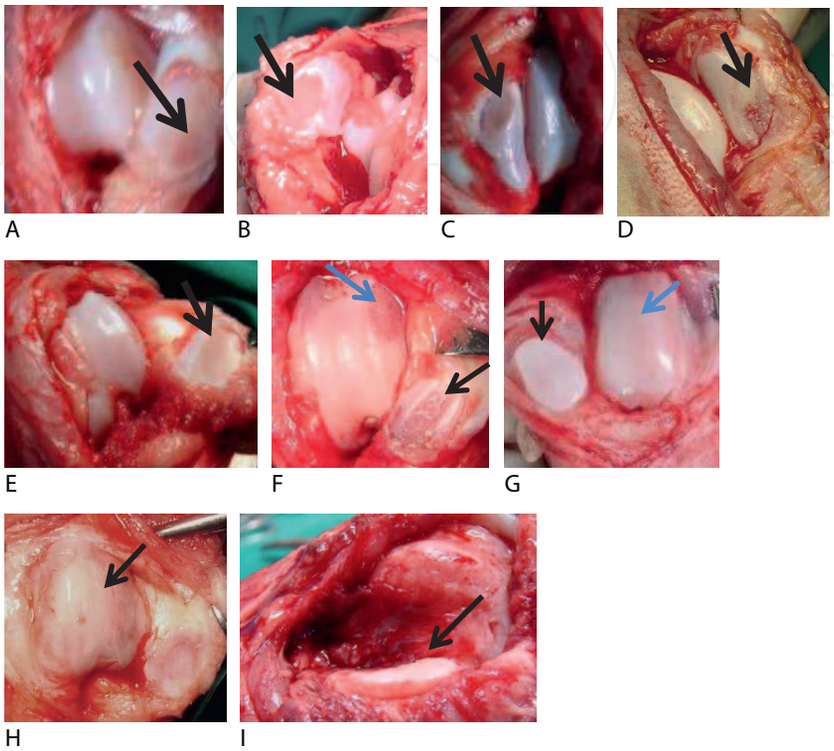

Figure 4. Photograph of the stifle joint of a dog subjected to surgery for patellar luxation. Notice the erosion of the patellar articular surface (black arrow). (A) Superficial erosion; (B) moderate erosion, (C and D) severe erosion; (E) severe erosion in the whole extension of the patella; (F) erosion of the edge of the medial condyle and erosion of the patella with subchondral bone exposure (blue and black arrows); (G) notice the flattened patellar surface (black arrow) and shallow trochlear groove (blue arrow); (H) convex femoral trochlea (black arrow); (I) patella concave.

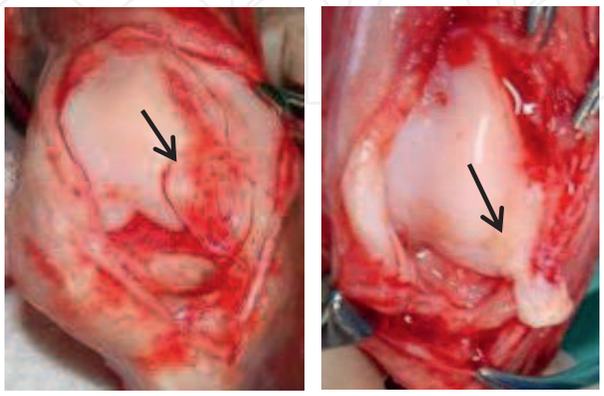

Figure 5. Photograph of the stifle joint of a dog subjected to surgery for patellar luxation. Notice the lesion by rubbing of the patella on the long digital extensor tendon (black arrow).

One rare instance of resorption of the patella was diagnosed in a dog with a grade III luxation. Some remnants of the bone were found adhered to the patellar tendon, while the central area was soft and exhibited loss of bone and cartilage. A 1-year history of severe lameness with frequent non-weight-bearing and grade II medial luxation in the contralateral limb existed. Resorption of the patella was treated with implantation of polyhydroxybutyrate patellar prosthesis. The outcome was favourable.

	Cartilage erosion												
	¼ patella		**½ patella**		**Full patella**		**Subchondral bone exposure**		**Flattened/concave patella**		**Enthesophytes**		**Assessed joints**
Severity	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**
Grade I	1	6.3	0	0	0	0	0	0	0	0	0	0	16
Grade II	22	18.6	17	14.4	0	0	6	5.1	12	10.1	11	9.3	118
Grade III	13	22.8	10	17.5	2	4.1	5	8.8	11	19.3	15	26.3	57
Grade IV	6	6.7	6	6.7	3	3.4	1	1.1	19	21.3	8	9.0	89
Total	42		33		5		12		42		34		280
Weight													Assessed dogs (n°)
<5 kg	22	21.4	5	6.0	3	2.8	0	0	14	13.0	13	12.0	108
5–15 kg	11	21.2	12	23.1	1	1.9	5	9.6	9	17.3	10	19.3	52
>15 kg	6	20.0	10	33.3	2	6.7	5	16.7	7	23.3	6	20.0	30
Total	39		27		6		10		30		29		190*
Age													(n°)
<12 months	6	7.0	5	5.8	3	3.5	5	5.8	13	15.1	5	5.8	86
12–24 months	3	15.0	1	5.0	0	0	0	0	1	5.0	3	15	20
>24 months	27	30.0	22	24.4	4	4.4	7	7.8	16	17.8	20	22.2	90
Total	36		28		7		12		30		28		196**

* The weight was not reported in 12 animals that were excluded from this assessment.
** The age was not reported in six animals that were excluded from this assessment.

Table 1. Estimated patellar lesions in dogs with patellar luxation treated at the Veterinary Hospital, FUMG, 2005–2016 according to the degree of luxation, body weight and age.

The frequency of cartilage erosion affecting one-fourth or one-half of the patella accompanied by subchondral bone exposure was higher among those with grade II or III luxation. Erosion of the full patellar surface occurred only in grade III or IV luxation. Patellar lesions were frequently observed on the lateral surface in medial luxation, but were seen on the medial surface in lateral luxation. Anatomical changes of the patella, such as a flattened or concave surface, occurred primarily in grade III or IV luxation, whereas enthesophytes were

most frequently found in grade III luxation. In animals older than 24 months, the lesions most frequently found were cartilage erosion affecting one-fourth or one-half of the patella, subchondral bone exposure and the presence of enthesophytes. The frequency of anatomical changes of the patella (flattened or concave surface) was highest among those older than 24 months of age and lowest in those aged 12–24 months. The frequency of patellar lesions was proportionally higher among those animals weighing more than 15 kg (**Table 1**). Joint mice and flap formation (**Figure 6**) were observed in two dogs with patellar luxation grade III. One dog was 6 months of age and weighed 22 kg and the other was 10 years old and weighed 5.8 kg.

Extra-patellar articular lesions	**Synovitis**		**Osteophytes**		**Shallow trochlea**		**Absent trochlea**		**Femoral condyle erosion**		**Thickened capsule**		**Subchondral bone exposure**		**Assessed joints**
Severity	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**	**%**	**n°**
Grade I	6	37.5	1	6.25	0	0	0	0	0	0	0	0	0	0	16
Grade II	41	34.7	37	31.4	56	47.5	4	3.7	41	34.7	25	21.2	4	3.7	118
Grade III	18	31.6	20	35.1	27	47.4	5	8.8	34	59.6	21	36.8	8	14.0	57
Grade IV	17	19.1	15	16.9	40	44.9	27	30.3	25	28.1	20	22.5	10	11.2	89
Total	82		73		123		36		100		66		22		280
Weight															Assessed dogs (n°)
<5 kg	20	18.5	20	18.5	42	38.9	17	15.7	25	23.1	17	15.7	3	2.8	108
5–15 kg	21	40.4	17	32.7	29	55.8	4	7.7	24	46.2	16	30.8	5	9.6	52
>15 kg	12	40	17	56.7	15	50.0	1	3.3	29	96.7	16	53.3	8	26.7	30
Total	53		54		86		22		78		49		16		190
Age															n°
<12 months	10	11.6	6	7.0	43	50.0	18	20.9	16	18.6	14	16.3	8	9.3	86
12–24 months	7	35.0	3	15.0	6	30.0	1	5.0	5	25.0	4	20.0	0	0	20
>24 months	33	36.7	43	47.8	40	44.4	4	4.4	36	40.0	23	25.6	9	10.0	90
Total	50		52		89		23		57		41		17		196

Table 2. Estimated extra-patellar articular lesions in dogs with patellar luxation treated at the Veterinary Hospital, UFMG, 2005–2016 according to degree of luxation, body weight and age.

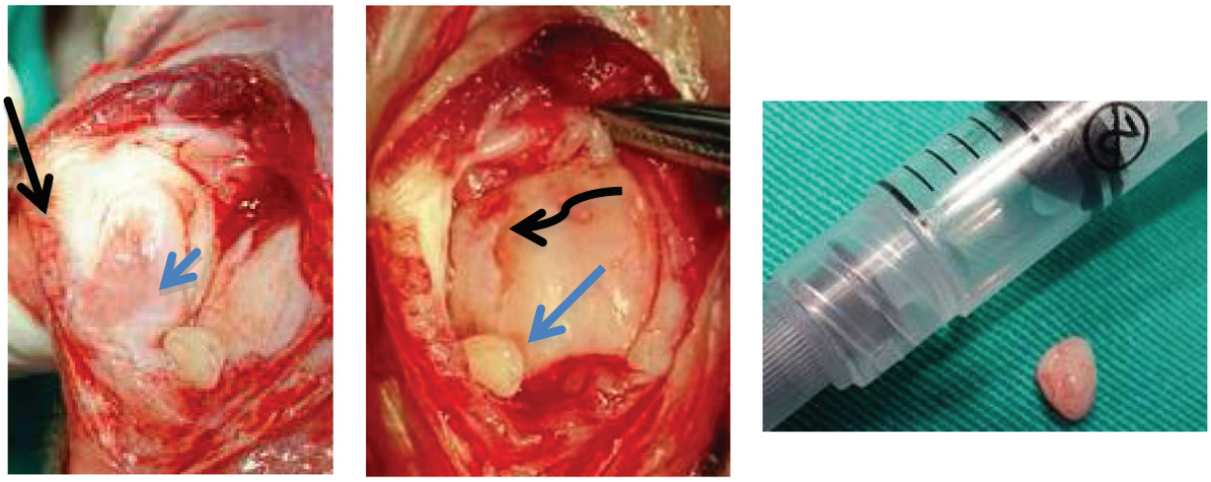

Figure 6. Photography of the stifle joint of a dog to surgery for patellar luxation. Notice the erosion of the patellar articular surface (black arrow), joint mice (blue arrow) and flap formation on the edge of the medial condyle (black S arrow).

Several extra-patellar lesions involving soft or hard tissue were observed. On intraoperative assessment, 29.3% of the joints exhibited synovitis, 26.1% had periarticular osteophytes, 43.9% had shallow trochlear grooves, 12.9% had absent trochlea, 35.7% exhibited cartilage erosion in condylar margins, 7.9% exhibited subchondral bone exposure in condylar margins, 23.6% had thickened capsules (**Table 2**), 3.6% had long digital extensor tendon injuries associated with lateral luxation, 0.7% exhibited joint mice and flap formation, 9.3% had ruptured cranial cruciate ligaments and 3.1% exhibited prolapse of the menisci. Synovitis occurred in 37.5% of the animals with grade I luxation. Periarticular osteophytes and shallow trochlear grooves were most frequently found among the animals with grade II luxation. Erosion of the femoral condylar margins and thickened capsules occurred most frequently among those with grade III luxation, while absent trochlear grooves were most frequently among those with grade IV luxation. Exposure of subchondral bone on the condylar margins predominated among those with grade III or IV luxation. Lesions in medial condyles were observed in joints in medial luxation, whereas lesions in lateral condyles were frequent in joints in lateral luxation. Extra-patellar lesions were proportionally higher among those weighing more than 15 kg.

The frequency of extra-patellar articular lesions according to age, body weight and degree of luxation is presented in **Table 2**.

Patellar re-luxation after surgical repair occurred in 12.9% of the joints distributed across all grades, ranging between 6% and 15%. Statistical analysis using the chi-square test suggests that no statistically significant differences exist between the variable "re-luxation patellar" and "degree of luxation," and "type of luxation (medial or lateral)" ($P > 0.05$).

The frequency of re-luxation according to type and degree of luxation is shown in **Table 3**.

Severity	n	Re-luxation (%)	NO re-luxation (%)
Grade I	16	1 (6.2)[a]	15 (93.8)[a]
Grade II	118	15 (12.7)[a]	103 (87.3)[a]
Grade III	57	7 (12.3)[a]	50 (87.7)[a]
Grade IV	89	13 (14.6)[a]	76(85.4)[a]
Total	280	36 (12.9)	244 (87.1)
Medial luxation	244	32 (13.1)[a]	212 (86.9)[a]
Lateral luxation	36	4 (11.1)[a]	32 (88.9)[a]

[a] In the columns, frequencies with different letters differ between groups using the chi-square test ($P < 0.05$).

Table 3. Estimated patellar re-luxation in dogs treated at the Veterinary Hospital, FUMG, 2005–2016 according to the type (medial or lateral) of luxation and degree of luxation. The rate of patellar re-luxation was assessed using the chi-square test.

A total of 13 luxated joints from eight cats were assessed, and all were medial luxations. Four (30.7%) were classified as grade IV, seven (53.4%) as grade III and two (15.4%) as grade II. Six cats were younger than 12 months and two were 12–24 months of age. Hip dysplasia was present in two cats (25%). Two cats from the same litter had patellar luxation grade IV associated with bone and tail deformity (**Figure 7**). One of them had unilateral patellar aplasia. These cats showed gait abnormalities, but were able to move around the house. Six were mixed-breed cats, one was Siamese, and one was an exotic cat. The surgical treatment was successful, and there was no recurrence of luxation.

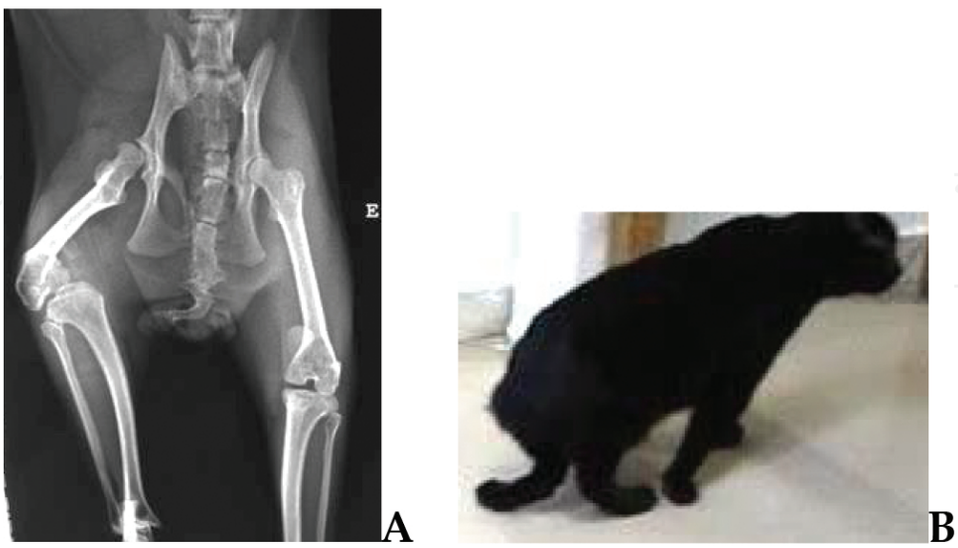

Figure 7. Anteroposterior radiograph of the limbs of a cat, showing: (A) bone deformity, and tail, dysplasia and medial patellar luxation grade III on the left side in a 7-month-old cat; (B) abnormal stance associated with bone deformities and medial patellar luxation grade III.

Lesions such as flattened patellar surface and shallow trochlear groove were also observed in cats with patellar luxation grades III and IV (**Figure 8**).

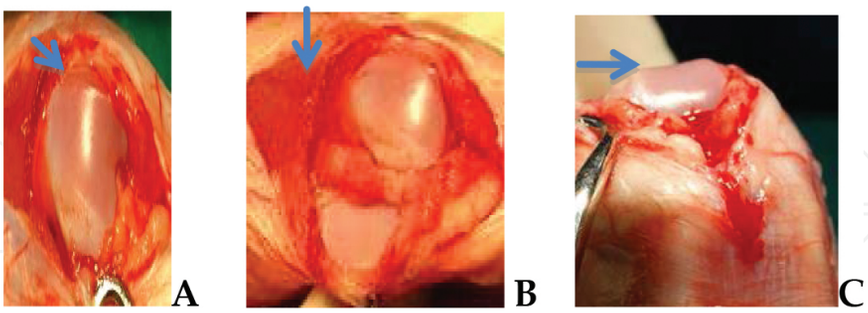

Figure 8. Photography of the stifle joint of a cat to surgery for patellar luxation. Notice the erosion of the edge of the medial condyle (A, blue arrow), flattened patellar surface (B, blue arrow) and shallow trochlear groove (C, blue arrow).

9. Discussion

Patella luxation in small animals is a condition in which early treatment has not been highlighted. The suggested course has been to wait for the manifestation of clinical signs [5, 6, 8, 21], which results in lameness. However, dislocation and subluxation are already characteristic clinical signs of anatomical abnormalities, which certainly will cause articular changes. Subluxation [6] is a clinical challenge, especially in obese and heavy dogs like English Bulldogs, making it difficult to diagnose the cause of progressive lameness [6].

In the literature, there are few descriptions of lesions occurring in the stifle joints of dogs with patellar luxation. Cartilage erosion on the patellar articular surface was reported by Remedios et al. [30]; however, they did not provide information about the extent of the erosion or the weight, age or degree of luxation. Daems et al. [31] reported cartilage erosions mainly in heavier dogs and with grade IV patellar luxation. Destruction of cartilage on the articular surface of the patella in both medial and lateral luxation and marked synovial reaction at the origin of the long digital extensor tendon in lateral luxation were reported by L'Eplattenier and Montavon [3]; Pérez et al. [14] reported erosion in the medial trochlear ridge and shallow trochlear groove.

The results of this study indicate a high frequency of patellar and extra-patellar lesions, especially in grade II and III luxations. According to the literature, although these animals exhibit intermittent and persistent lameness, respectively [1, 5, 32], they continue to use the affected limb for ambulation. These facts account for the larger number of lesions found among animals with grade II or III luxation. The use of the affected limb leads to joint wear. This is in contrast to animals with grade IV luxation that do not bear their weight on the affected limb, but drag or carry it while the weight is transferred to the front limbs.

Roy et al. [19] did not find a significant association between the degree of luxation and the progression of radiological articular changes, which suggests that some of the alterations that are visible during surgery might not be detectable in radiological exams.

Because of the anatomy and biomechanics, the friction between the articular surfaces of the patella and femoral trochlea will cause erosion of the medial femoral condyle and lateral patellar surface in medial luxation, and of the lateral femoral condyle and medial patellar surface in lateral luxation [8]. Subluxation also causes wear of the articular surface of the patella and flattening of the condylar edge that favours dislocation [6].

The quadriceps mechanism is responsible extension, and a healthy patellofemoral joint is essential for implementation of this function. The quadriceps, patella, trochlea, patellar tendon and tibial tuberosity must be aligned. Abnormal alignment of the extensor mechanism interferes with limb flexion and extension [8] and compromises its function.

Misalignment of the quadriceps leads the kneecap to become dislocated and press and brush on the lateral or medial condyle surface during limb movement. Erosion is observed in dislocations when the quadriceps' extension function is maintained. In these cases, the pressure of the quadriceps extensor during movement, acting on an improper surface for receiving the force, causes wear injuries. The injury is more severe in animals weighing more than 15 kg. The greater frequency of lesions in grade II and III luxations can be explained by moderate functional changes that allow member extension, promoting compression between the patella and condyle edge. In grade IV luxation, there is a significant decreased range of extension in the joint associated with contracture of the soft tissues caudal to the joint [6, 8] (**Figure 2B, D**), which prevents the friction pressure between the condyle and patellar edge. Patellar luxation is also responsible for the resulting absence of a trochlear groove.

In this study, the frequency and severity of articular lesions were higher among the animals weighing at least 15 kg, as Daems et al. [31] observed. This finding might be attributed to the biomechanical instability resulting from the greater load to which the stifle joint is subjected. Biomechanical stability is considered to be essential for an appropriate supply of blood to the articular cartilage [3], because inadequate nutrition results in joint degeneration, which is observed in cases of patellar luxation.

The high frequency of patellar lesions among animals aged older than 24 months might be the result of disease duration. As some authors have observed [5, 31, 33, 34], patellar luxation mainly affects young animals still in the growing phase, and they are often not referred for treatment for several reasons, among which, the lack of symptoms or the presence of only mild clinical signs, stands out. Consequently, alterations of the patella resulting from chronic friction have already appeared by the time surgery is performed. These are sufficient reasons for early surgical intervention based on the cause—patellar luxation—and not in the presence of clinical signs as reported in the literature [5, 6, 8, 21].

The severity of the long digital extensor tendon injuries, also mentioned in the literature [6], varies according to the chronicity of the case (**Figure 5A, B**) and affects small and large dogs.

As mentioned in the literature [21], severe skeletal changes associated with unilateral patellar aplasia were observed in one cat (**Figure 7A, B**), whose two brothers also had grade III patella luxation and no tail. The litter was a result of crosses between brothers.

The re-luxation rate observed in this study (12.9%) is within the range reported by Arthurs and Langlay-Hobbs [35] and Wandgee et al. [35], although rates up to 50% have been reported [36]. Arthurs and Langley-Hobbs [35] report a greater frequency of major and patellar re-luxation complications in dogs weighing 20 kg or more compared to smaller dogs. In this study, two (6.6%) re-luxations were observed among the 30 dogs that weighed more than 20 kg.

Recurrence of patellar luxation is a common complication associated with surgery; among the factors that contribute to re-dislocation are the severity of the lesions, because grade III and IV luxations indicate poor shaft alignment, failure to align the tuberosity of the tibia with trochlea, and contracture of soft tissues caudal to the joint, affecting the post-operative joint range of motion [6, 8]. As with the loss of convexity of the patella, it loses its slot in the femoral trochlea. Daems et al. [31] postulate that one of the reasons for surgical failure in stable post-surgical patellae is the presence of cartilage erosion. Mostafa et al. [14] proposed that the proximodistal malalignment of the patella (patella alta and baja) influenced re-luxation. Patella alta is defined as the proximal displacement of the patella within the femoral trochlear groove. It has been speculated that patella alta may play a role in canine patellar luxation [12, 37]. The position of the patella in the trochlea, as Mostafa et al. [14] observed, might be the reason for one case of patellar re-luxation in our study. One dog weighing more than 20 kg with recurrent grade II bilateral medial luxation was evaluated. To assess the patellar position on the femoral trochlea, radiographic evaluation was performed according to the method described by Mostafa et al. [13]. After osteotomy of the tibial tuberosity, as described by Johnson et al. [37] and distally transposing 0.5 cm the tibial tubercle, the patella remained in the groove.

We found no instance of implant failure among animals weighing at least 15 kg because the implants used were compatible with the dogs' weights.

The treatment was challenging in both cats with severe deformities of the distal femur, tibia and tail. It was not possible to correct all deformities, but there was improvement in ambulation. Although they were able to move around the house, as related by Hubler et al. [38], the gait abnormalities were extremely severe.

Post-operative measures, such as activity restriction and physical therapy, contribute to the success of treatment and might prevent some post-operative complications and favour an early recovery of muscle mass and the functional performance of the limb.

10. Conclusion

Based on these results, we conclude that patellar luxation should undergo surgical repair even when the clinical signs of disease are mild or absent, because this condition triggers patellar and extra-patellar changes that result in a more difficult surgery and promote the

progression of joint degeneration, thus reducing the odds of a full and painless recovery of joint function.

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