Received: 14 September 2023 | Revised: 26 January 2024 | Accepted: 5 February 2024

DOI: 10.1002/vetr.3994

VetRecord

ORIGINAL RESEARCH

Outcome of surgical correction of medial patellar luxation in dogs weighing less than 10 kg

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Abstract

Background: Various trochleoplasty techniques, including trochlear wedge recession (TWR) and trochlear block recession (TBR), are used to treat dogs with medial patellar luxation (MPL). However, the objective outcomes of these surgical procedures are underreported.

Methods: Medical records were obtained for dogs weighing less than 10 kg that underwent either TWR or TBR and tibial tuberosity transposition to address grade I–III MPL. Long-term (at least 1 year after the last procedure) follow-up included orthopaedic and radiographic examinations, such as osteoarthritis score (OAS), ground reaction force (GRF) analysis and canine brief pain inventory (CBPI).

Results: Overall, 20 dogs (26 stifles) were followed up in the long term. Minor postoperative complications, medial patellar reluxation (MPR) and intermittent lameness occurred in 46.15%, 19.23% and 15% of the dogs, respectively. MPR occurred only in TWR-treated stifles, while mean OAS increased in all groups. Using the CBPI, the owners perceived an excellent or very good outcome in 95% of dogs.

Limitations: The limitations of the study include its retrospective observational nature, a lack of randomisation and a small sample size.

Conclusion: Surgical treatment resulted in a favourable outcome. GRF analysis could detect subtle differences in weight bearing in dogs treated for MPL, which might not be apparent clinically. There might be a higher risk for reluxation for TWR. However, a larger-scale prospective study would be required to find which treatment is superior.

INTRODUCTION

Although patellar luxation can affect any size dog, small and toy breeds appear predisposed.[1] The structural changes associated with patellar luxation range from mild changes in the joint capsule to severe bone deformities; however, the pathophysiology remains unelucidated.[2] Patellar luxation can be classified based on origin (congenital or traumatic) or direction (medial or lateral).[2] Medial patellar luxation (MPL) is more common.[3,4] Luxation is further classified into four grades based on the severity of the condition.[5] Generally, surgery is recommended for all grade III and IV MPLs.[6] Furthermore, corrective surgery of grade II MPLs is performed if it leads to lameness.[6] However, occult MPL leads to clinically relevant lameness in 50% of cases within 4 years.[7] A previous retrospective study found that surgical strategies aiming to restore quadriceps muscle alignments, such as transposition of the tibial tuberosity and trochleoplasties, minimise the risk of postoperative medial patellar reluxation (MPR), whereas performing soft tissue procedures only, such as medial desmotomy, capsulectomy, the lateral imbrication of the capsule and the fascia, anti-rotational sutures and quadriceps release, may lead to higher major complication rates.[8] There are various trochleoplasty techniques, including trochlear wedge or trochlear block recession (TWR or TBR, respectively) trochleoplasty, rotating dome, kite shield or semicylindrical trochleoplasty and medial ridge elevation trochleoplasty.[6,9–11]

A cadaveric biomechanical study[12] revealed that the TBR offers a larger contact area between the patella and trochlea than the TWR and a greater resistance to patellar luxation when the stifle is extended. The authors theorised that this could lead to less severe arthritis development and improved outcomes compared with TWR.[12] However, there are currently no published data concerning the objective outcome evaluation of dogs treated surgically for MPL, particularly with regard to different trochleoplasty techniques. Although pre- and postoperative kinetic stance analyses are reported,[13] to our best knowledge, kinetic gait analysis remains unreported. Our study aimed to report the outcomes of dogs with MPL treated with either TWR or TBR, based on long-term follow-up orthopaedic examination, kinetic gait analysis, radiographic osteoarthritis score (OAS) and a validated client outcome measure.[14] Our primary hypothesis was that there would be no difference in the observed outcomes and complications between the TWR and TBR.

MATERIALS AND METHODS

Selection criteria

Data for 197 dogs weighing less than 10 kg treated with TWR or TBR for grade I–III MPL between January 2006 and August 2021 were obtained from our institution's medical database. The owners of the animals were contacted via telephone or email and invited for a follow-up examination at least 1 year after the index surgery, as per the proposed definition of long-term follow-up.[15] In the case of bilaterally operated dogs, the follow-up examination was 1 year after the index surgery of the later-operated leg. The exclusion criteria were pre-existing conditions or surgery of the hindlimb other than MPL, an intraoperative finding of partial or complete cranial cruciate rupture, any other orthopaedic surgery of the hindlimb between the index surgery and follow-up (apart from implant removal or revision of the index surgery) and unavailability for a follow-up examination. Included cases were further stratified based on whether the dogs were unilaterally or bilaterally affected and unilaterally or bilaterally operated. This resulted in three groups: unilaterally affected (group I), bilaterally affected but unilaterally operated (group II) and bilaterally affected and bilaterally operated (group III). At the long-term follow-up examination, all dogs received a complete physical and orthopaedic examination, ground reaction force (GRF) measurements and radiographic projections of both stifles.

Physical and orthopaedic examination

Clinical examination included evaluation of stance and gait, palpation of the periarticular soft tissue, joint effusion, stifle range of motion and side of luxation. MPL was classified according to Putnam's grading system, as depicted in Table 1.[5] Lameness was described using a previously reported five-point grading system.[16]

TABLE 1 Putnam's grading of patellar luxation[5]

Grade 0	Patella cannot be luxated, regardless of the limb's position.
Grade I	Patella can be manually luxated but returns to normal position when released.
Grade II	Patella luxates with stifle flexion or on manual manipulation and remains luxated until stifle extension or manual replacement occurs.
Grade III	Patella is luxated continually and can be manually replaced but reluxates spontaneously when manual pressure is removed.
Grade IV	Patella is luxated continually and cannot be manually replaced.

Analysis of GRFs

The GRF analysis was performed in a quiet room with carpet, including a 203.2 × 54.2 cm Zebris FDM Type 2 (Zebris Medical) pressure plate with a sampling rate of 100 Hz, placed on a 7-m runway. The measurement trials were video recorded using a Panasonic NV-MX500 camera, and the data were stored using a pressure analyser (Michael Schwanda, version 4.8.5.0).

The owners walked the dogs over the plate until at least five valid gait cycles were obtained without the dog changing its gait, turning its head or being corrected by the owner with a leash. Individual footfall prints were manually identified through video recordings using custom software (Pressure Analyser 1.3.0.2; Michael Schwanda). For each limb, peak vertical force (PFz) expressed in Newtons, vertical impulse (IFz) expressed in Newton-seconds and percentage of the stance phase (TPFz) were calculated. TPFz represents the time of occurrence of PFz during the stance phase, with the total duration of the stance time defined as 100%. The symmetry index (SI [%]) of PFz or IFz between the contralateral limb pairs was calculated as previously described and normalised using a previously published formula,[17] in which PFz and IFz for the individual limbs were expressed as a percentage of the total force (%TF). An SI of 0% represents perfect symmetry between the contralateral limb pair. SI larger than 4% was considered clinically relevant.[18]

Radiographic examination and scoring

Standard mediolateral and caudocranial views of both stifles were obtained preoperatively. Follow-up radiographs were obtained without sedation. All the images were anonymised and randomised, before being scored according to previously published OAS[19] by a single examiner (J.V.).

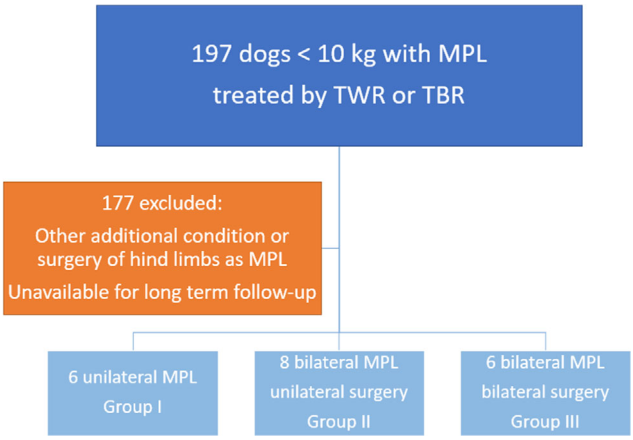

FIGURE 1 Diagram of the exclusion process and stratification of dogs into groups. MPL, medial patellar luxation; TBR, trochlear block recession; TWR, trochlear wedge recession

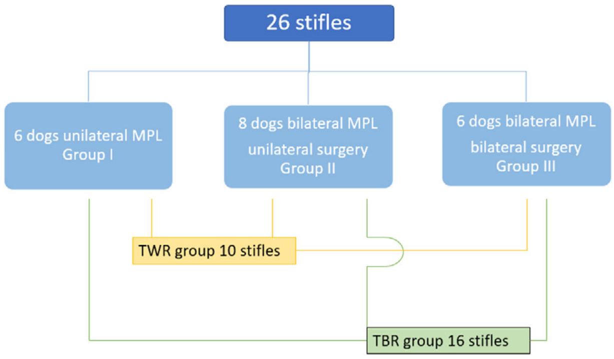

FIGURE 2 Stratification of the included stifles into trochleoplasty-type groups. MPL, medial patellar luxation; TBR, trochlear block recession; TWR, trochlear wedge recession

Surgical procedure and complications

The trochleoplasty performed was recorded as either TWR[20] or TBR[21] based on medical records. Additional procedures included tibial tuberosity transposition (TTT[22]; with or without tension band), fabello-tibial anti-rotational suture and lateral imbrication of the joint capsule or fascia. Bilateral cases underwent staged procedures.

Complications were classified as catastrophic, major or minor; also as perioperative or short- or long-term postoperative.[15] Pin removal has been considered a minor complication.[23] Similarly, dogs that experienced reluxation were classified according to whether revision surgery was performed or not.[23] Perioperative and short-term postoperative complications were recorded based on the medical records, whereas for long-term postoperative complications, a follow-up clinical examination was obtained.

Owner-based outcome evaluation

The canine brief pain inventory (CBPI)[14] was used to assess the outcomes of dogs from the owners' perspective. The owners completed the questionnaire during the last follow-up orthopaedic examination.

RESULTS

Twenty dogs, with 26 operated stifles, fulfilled the selection criteria. Six dogs (30%) were unilaterally affected (group I), eight (40%) were bilaterally affected but unilaterally operated (group II) and six (30%) were bilaterally affected and bilaterally operated (group III), as shown in Figure 1.

There were seven Chihuahuas (35%), three crossbreeds (15%), two Russian Toy Terriers (10%) and two Yorkshire Terriers (10%). There was one each (5%) of Miniature Pinscher, Affenpinscher, Whippet, French Bulldog, Spitz and Bolonka Zwetna. The 20 dogs comprised seven (35%) entire females, five (25%) neutered females, four (20%) entire males and four (20%) neutered males. The mean bodyweight at the time of follow-up was 6.8 (4.3–10.0) kg, 4.1 (2.5–8.8) kg and 3.8 (2.1–9.9) kg for groups I, II and III, respectively.

The median age at the time of surgery for the unilaterally operated dogs was 30 (9.5–92.5) months. The median age at the time of surgery for the bilaterally operated dogs was 18 (10.5–20.5) months and 28 (15–59) months for the first and second sides, respectively. The median time from surgery to follow-up was 35.5 (14–96) months for unilaterally operated dogs, and the median time from surgery on the second side to follow-up was 41 (15–68) months for bilaterally operated dogs. A review of preoperative medical records revealed grade I, II and III MPLs before surgery in two (7.7%), seven (26.9%) and 17 (65.4%) stifles, respectively. TWR and TBR were performed in 10 (38.5%) and 16 (61.5%) stifles, respectively. Stratification of the stifles into groups and subgroups is depicted in Figure 2. Nine (90%) TWR stifles had grade III MPL preoperatively and one (10%) had grade I MPL, while eight (50%) TBR stifles had grade III MPL, seven (43.7%) had grade II MPL and one (6.3%) had grade I MPL before surgery.

Additionally, TTT stabilised with K-wires only (three K-wires), TTT stabilised with two K-wires and tension band wire, TTT stabilised with K-wires alone or together with tension band wire or together with anti-rotational suture, and anti-rotational suture alone was performed in 18 (69.2%), four (15.4%), one (3.8%) and two (7.7%) stifles, respectively. Capsulorrhaphy and imbrication were performed routinely in all cases.

Peri- and postoperative complications

The only intraoperative surgical complication was a distal tibial tuberosity cortex fracture while performing the TTT in one stifle (3.85%), which was addressed by placing a tension band wire immediately. No catastrophic or major postoperative complications were observed. Twelve dogs experienced minor complications (46.2%). The most common complications were pin associated, such as seroma or pin mobilisation due to osteolysis (six stifles, 23%). In two stifles (7.69%), the pin was removed due to complications. The second most common complication was MPR (four stifles, 15.4%). Two dogs (7.7%) experienced swelling over the pins and prolonged mid-term lameness, but both were spontaneously resolved. Overcorrection with consequent grade II lateral patellar luxation occurred in one stifle (3.85%) treated with TWR, TTT and anti-rotational sutures.

Long-term follow-up

The long-term follow-up orthopaedic examination did not reveal any stance abnormalities in the dogs, whereas three dogs (15%) showed grade II lameness (weight bearing with frequent but intermittent lameness)[16] on the operated limb. While the patellofemoral joints of 21 operated stifles (76.94%) were reduced, with no signs of luxation, grade I and III MPR was evident in four (15.38%) and one (3.85%) operated stifles, respectively. Furthermore, grade II lateral patellar luxation was evident in one operated stifle (3.85%). This dog (with a grade III MPL before surgery) was treated with TWR and showed a grade II lameness[16] on the operated limb at the long-term follow-up. No other dogs with MPR showed any lameness. The other two dogs with grade II lameness, treated with TBR for grade III MPL, had stable patellae. MPR occurred only in TWR-treated stifles.

The evaluation at short- to mid-term follow-up (up to11 months), based on extracted information from the clinical records, revealed MPR in 11.7%, 0% and 0% for preoperative grades III, II and I, respectively; at the long-term follow-up, it was 29.4%, 0% and 50%, respectively.

GRF analysis

The PFz (%TF), IFz (%TF) and symmetry indices are reported in Tables 2–4, including the breed, grades of patellar luxation before surgery and at follow-up, and surgical techniques employed.

The mean PFz (%TF) for the operated versus non-operated hindlimb was 17.78 ± 1.49 versus 18.75 ± 1.88 and 18.21 ± 1.58 versus 19.67 ± 1.73 for groups I and II, respectively. The mean IFz (%TF) for the operated versus non-operated hindlimb was 16.14 ± 1.91 versus 17.15 ± 1.69 and 15.91 ± 1.79 versus 17.23 ± 1.73 for groups I and II, respectively. Two dogs in group I and five in group II had a PFz (%TF) SI higher than 4%, with a higher PFz (%TF) for the non-operated hindlimb in all cases.

Considering all the dogs, including the six bilaterally operated cases, 10 dogs (50%) had an SI higher than four for either PFz (%TF), IFz (%TF) or both. Of these 10 dogs, two dogs showed grade II lameness[16] on the operated hindlimb, with no evidence of patellar luxation. Furthermore, one other dog with grade II lateral patellar luxation due to overcorrection also showed a grade II lameness.[16] The remaining seven dogs showed

TABLE 2 Description and results of ground reaction force analysis of group I

No.	Breed	Initial PLG OL	PLG OL at follow-up	Type of TP	Additional procedures	PFz (%TF) OL	PFz (%TF) CL	SI PFz (%)	IFz (%TF) OL	IFz (%TF) CL	SI IFz (%)
1	Crossbreed	III	0	TBR	TTT + 2 pins	19.05	18.47	1.55	17.31	16.9	1.19
2	Miniature Pincher	II	0	TBR	TTT + 2 pins	15.85	15.88	0.09	13.35	14.16	2.97
3	Crossbreed	III	0	TBR	TTT + 3 pins	18.25	17.58	1.87	18.97	18.72	0.67
4	French Bulldog	I	0	TBR	TTT + 2 pins + tension band	15.86	19.11	9.29	15.06	18.88	11.26
5	Affenpinscher	III	0	TWR	TTT + 2 pins	19.84	19.35	1.24	17.4	15.95	4.34
6	Chihuahua	III	0	TBR	TTT + 2 pins	17.84	22.08	10.61	14.73	18.29	10.08

Abbreviations: CL, contralateral limb; IFz (%TF), vertical impulse normalised to total force; OL, operated limb; PFz (%TF), peak vertical force normalised to total force; PLG, grade of patellar luxation; SI, symmetry index; TBR, trochlear block recession; TP, trochleoplasty; TTT, tibial tuberosity transposition; TWR, trochlear wedge recession.

TABLE 3 Description and results of ground reaction force analysis of group II

No.	Breed	Initial PLG OL	Initial PLG CL	PLG OL at follow-up	PLG CL at follow-up	Type of TP	Additional procedures	PFz (%TF) OL	PFz (%TF) CL	SI PFz (%)	IFz (%TF) OL	IFz (%TF) CL	SI IFz (%)
7	Chihuahua	III	III	I	III	TWR	TTT + 2 pins	21.03	23.19	4.91	19.62	20.07	2.68
8	Crossbreed	III	I	0	I	TWR	TTT + 2 pins	19.27	19.92	1.67	17.57	18.52	2.63
9	Yorkshire Terrier	III	II	0	III	TBR	TTT + 2 pins	15.21	18.82	10.59	13.22	16.49	11.02
10	Chihuahua	I	I	I	I	TWR	TTT + 2 pins + tension band	18.98	19.52	7.22	14.98	15.76	7.29
11	Spitz	II	II	0	III	TBR	TTT + 2 pins + tension band	17.24	19.68	6.63	15.53	17.74	6.65
12	Bolonka Zwetna	III	II	0	II	TWR	TTT + 2 pins	17.64	16.76	2.55	16.01	16.47	1.42
13	Chihuahua	III	II	0	III	TBR	TTT + 2 pins	17.93	18.67	2.03	15.16	14.63	2.75
14	Yorkshire Terrier	III	III	II LPL	III	TWR	TTT + 2 pins + FTAS	18.38	20.81	6.21	15.2	17.49	7.03

Abbreviations: CL, contralateral limb; FTAS, fabello-tibial anti-rotational suture; IFz (%TF), vertical impulse normalised to total force; LPL, lateral patellar luxation; OL, operated limb; PFz (%TF), peak vertical force normalised to total force; PLG, grade of patellar luxation; SI, symmetry index; TBR, trochlear block recession; TP, trochleoplasty; TTT, tibial tuberosity transposition; TWR, trochlear wedge recession.

TABLE 4 Description and results of ground reaction force analysis of group III

No.	Breed	Initial PLG LL	Initial PLG RL	PLG follow-up LL	PLG follow-up RL	Type of TP LL	Type of TP RL	AP LL	Additional procedures RL	PFz (%TF) LL	PFz (%TF) RL	SI PFz (%)	IFz (%TF) LL	IFz (%TF) RL	SI IFz (%)
15	Chihuahua	III	II	III	0	TWR	TBR	TTT + 2 pins	TTT + 2 pins	17.73	19.82	5.56	14.43	16.85	6.82
16	Chihuahua	III	III	0	0	TBR	TBR	TTT + 2 pins	TTT + 2 pins	17.27	19.95	7.21	13.22	16.85	12.07
17	Chihuahua	II	III	0	0	TBR	TBR	TTT + 2 pins	TTT + 2 pins	18.14	18.49	0.95	16.64	16.15	1.49
18	Whippet	II	II	0	0	TBR	TBR	TTT + 2 pins + tension band	TTT + 2 pins + tension band	22.06	23.37	0.54	18.51	18.20	0.85
19	Russian Toy Terrier	III	II	0	0	TWR	TBR	TTT + 2 pins	TTT + 2 pins + tension band	15.91	17.11	3.61	13.07	14.81	6.27
20	Russian Toy Terrier	III	III	I	I	TWR	TWR	TTT + 2 pins	TTT + 2 pins	17.99	18.79	2.18	14.80	14.71	0.29

Abbreviations: IFz (%TZ), vertical impulse normalised to total force; LL, left hindlimb; PFz (%TZ), peak vertical force normalised to total force; PLG, grade of patellar luxation; RL, right hindlimb; SI, symmetry index; TBR, trochlear block recession; TP, trochleoplasty; TTT, tibial tuberosity transposition; TWR, trochlear wedge recession.

TABLE 5 Mean osteoarthritis scores (OASs) of the groups before surgery and at follow-up

	Group I: operated stifle (mean ± SD)	Group I: non-operated stifle (mean ± SD)	Group II: operated stifle (mean ± SD)	Group II: non-operated stifle (mean ± SD)	Group III (mean ± SD)
Mean OAS before (first) surgery	20.17 ± 3.80	17 ± 1.74	17.25 ± 1.48	16.5 ± 1.12	15.83 ± 0.89
Mean OAS at follow-up	24 ± 4.20	18.67 ± 2.74	20 ± 1.66	18 ± 1.41	19 ± 1.35

Abbreviation: SD, standard deviation.

TABLE 6 Mean osteoarthritis scores (OASs) of the subgroups, based on the type of trochleoplasty performed, before surgery and at follow-up

Subgroup	Mean OAS ± SD of operated stifles before first surgery	Mean OAS ± SD of operated stifles at follow-up	Mean increase in OAS ± SD operated stifles
TBR	17.63 ± 3.14	21.31 ± 3.13	3.69 ± 1.36
TWR	16.5 ± 1.75	18.8 ± 1.78	2.3 ± 1.42

Abbreviations: SD, standard deviation; TBR, trochlear block recession; TWR, trochlear wedge recession.

no obvious lameness. Two of those seven dogs had grade I MPR, and one had grade III MPR.

OAS

The mean OASs of the groups before surgery and at follow-up are shown in Table 5 and the mean OASs of the subgroups based on the type of trochleoplasty are shown in Table 6. The mean OAS increased between the initial and long-term follow-up examinations for all groups.

CBPI

The mean pain severity score was 0.7 (0–7), and the mean pain interference score was 1.5 (0–9). The owners perceived excellent, very good and good overall outcomes in 13 (65%), six (30%) and one (5%) dogs, respectively. In the four dogs with MPR and one with lateral patellar luxation, the mean pain severity score was 1.4 (0–7), and the mean pain interference score was 1.6 (0–4). The owners perceived excellent, very good and good overall outcomes in three (60%), one (20%) and one (20%) dogs, respectively.

DISCUSSION

Our study reports the outcomes of dogs with MPL treated with either TWR or TBR, based on long-term follow-up orthopaedic examination, postoperative kinetic gait analysis, radiographic OAS and a validated client outcome measure.[14]

Most dogs were sound on the operated limb at long-term follow-up, but four (15%) showed frequent but intermittent lameness on the operated hindlimb. The cause of lameness was evident in only one dog with grade II lateral patellar luxation caused by overcorrection. The remaining three dogs had stable patellofemoral joints, and the follow-up examination did not reveal any suspicion of an orthopaedic problem in another joint of the affected limb. Some dogs treated for MPL remain lame despite stable patellae.[24] This could be caused by osteoarthritis progression or increased retropatellar pressure, similar to patellofemoral pain syndrome described in human literature.[25]

The mid-term follow-up medial reluxation rate was 7.69%; this percentage increased to 19.23% at long-term follow-up. While the mid-term reluxation rate appears to be in concordance with the findings of a previous study,[24] the increased occurrence of MPR at long-term follow-up might reflect the slow, progressive failure of additional soft tissue procedures, further abrasion of the newly created trochlear ridges or progression of osteoarthrosis. However, the difference in clinical findings at mid- and long-term follow-up could have been introduced by interobserver bias as well. Unfortunately, there is a paucity of reports on long-term reluxation rates, although long-term data are of clinical value, especially with respect to operating on the contralateral stifles with MPL without lameness. Due to the study's retrospective nature, we could not control factors that could potentially lead to the reluxation, such as not achieving successful realignment of the quadriceps mechanism. Possible causes include insufficient lateral transposition of the tibial tuberosity or insufficient surgical planning to address possible distal femoral varus, femoral torsion, proximal tibial valgus or torsion. While clinically relevant angular deformities are less common in dogs with lower grades of MPL,[26] it may be prudent to consider including preoperative computed tomography scans in future prospective studies. One dog experienced lateral patellar luxation as a result of an overcorrection; this might be attributed to excessive lateralisation of the tibial tuberosity or excessive tension from any of the soft tissue procedures.

The mean PFz (%TF) and mean IFz (%TF) in groups I and II were lower for the operated hindlimbs than for the non-operated hindlimbs. However, due to the retrospective nature of patient recruitment, making direct comparisons based on kinetic gait analysis results is challenging. A prospective approach would facilitate the comparison of PFz and IFz before surgery and at follow-up. Additionally, evaluating PFz and IFz in relation to other limbs is crucial. Therefore, our population has been stratified into unilaterally affected and unilaterally operated (group I), bilaterally affected but unilaterally operated (group II) and bilaterally operated (group III).

Analysing group I allows us to assess the impact of the disease and its correction through surgery compared to the non-affected limb, considering the kinetic analysis before surgery. Comparing the means of the hindlimbs in group II helps evaluate the effect of performing surgery versus not performing surgery. Ideally, the contralateral limbs in group II should have the same grade of patellar luxation. Conducting a post hoc power analysis based on the mean PFz of the operated hindlimbs in group II suggests that 18 stifles per group (operated vs. non-operated) with the same luxation grade would be required to achieve sufficient power (80% with $\alpha = 0.05$) to detect a treatment effect on PFz (%TF). Similarly, it would require 28 stifles per group to evaluate IFz (%TF).

We identified clinically evident grade II lameness[16] in the operated hindlimbs exclusively, with one dog in group I, one in group II and one in group III. Lateral patellar luxation was observed only in the dog from group II; the remaining dogs had normally positioned patellae. Kinetic gait analysis confirmed SIs higher than 4% for PFz (%TF) or IFz (%TF) in all three dogs, and seven additional dogs exhibited clinically relevant SIs. Interestingly, out of the 10 dogs with clinically relevant SIs, only half showed evidence of patellar misalignment (including the case with lateral luxation due to overcorrection). Hence, factors such as osteoarthritis must be considered responsible for the observed changes in kinetic gait analysis.

We noted an increase in the mean OAS for both operated and non-operated stifles. Interestingly, the mean OAS of the operated stifles of the dogs in group II was higher at follow-up than the mean OAS of their contralateral non-operated stifles, indicating a possible impact of trochleoplasty on the development of osteoarthritis. A post hoc power analysis, utilising the observed means, suggests that 24 dogs with bilateral patellar luxation of the same grade undergoing unilateral surgery would be required to achieve sufficient power (80% with $\alpha = 0.05$) to detect a treatment effect on OAS. Notably, Roy et al. found no statistically significant difference in radiographic evidence of osteoarthritis between surgically and conservatively treated stifles in 12 dogs with bilateral patellar luxation and unilateral surgery at a mean follow-up of 33 months.[16] This sample size may be insufficient to draw definitive conclusions about the surgery's effects despite differences in scoring methodology.

The induction of osteoarthritis through trochleoplasty raises concerns. Although Alam et al.[27] previously reported that arthrotomy does not induce osteoarthritis compared to patellar luxation per se, their study's methodology should be considered. The study compared the effect of a small incision in the joint capsule, similar to an arthroscopic portal, to experimentally induced MPL through patella–fabella suture, capsulorrhaphy and lateral release. Dogs were euthanased at 12 weeks post-surgery, revealing gross and histological changes in cartilage in the treated group compared to the sham arthrotomy group. Van der Zee reported severe osteoarthritic lesions due to trochleoplasties in five dogs.[28] Furthermore, any insult to the joint cartilage results in degenerative joint disease[29] and introduces defects that heal with fibrocartilage patches instead of hyaline cartilage, which is not of the same quality.[30] Hence, there is a possibility that trochleoplasty could result in a higher OAS compared to the non-operated group, as suggested by the trend in our results. However, a more extensive study would be necessary to establish or refute this correlation. In the interim, surgeons should carefully assess whether a patient requires trochleoplasty or if alternative procedures would suffice.

Significantly, we observed a smaller increase from preoperative OAS to follow-up OAS for the TWR-treated stifles than the TBR-treated stifles. A post hoc power analysis, using the observed means, indicates that a group of at least 15 dogs, ideally with the same grade of patellar luxation per trochleoplasty type, would be needed to achieve sufficient power (80% with $\alpha = 0.05$) to detect an effect of trochleoplasty type on the increase in OAS.

A previous cadaveric study by Johnson et al. biomechanically evaluating TWR and TBR and finding a larger contact area between the patella and the trochlea during the stifle extension for TBR concluded that TBR could lead to less severe osteoarthritis.[12] Also, in our population, we found evidence of MPR only in TWR-treated stifles. Although deeper coverage might mechanically help prevent reluxation, their conclusion that TBR causes less osteoarthrosis seems to be controversial concerning the biomechanical cadaveric design of the of the study. Furthermore, Daems et al. hypothesised that incongruity of the patella with the newly created trochlea might lead to abnormal pressure distribution.[31] This theory is supported by the finite element model analysis reported by Kaiser et al. using human stifle models obtained with magnetic resonance. The authors found that deepening trochleoplasty may dramatically increase retropatellar contact pressures.[32] Therefore, it is also possible that TBR could lead to more severe osteoarthrosis than TWR owing to an increase in patellofemoral contact, and creating a deeper trochlea without appropriate realignment of the quadriceps mechanism could lead to progressive abrasion of the medial ridge.

The evaluation of medical records revealed that intraoperative complications were rare (3.8%) and correctable during the index surgery without impact on the postoperative period. Complication rates in our study population were consistent with previously published data.[33–35]

The owners reported good to excellent overall outcomes in 95% of cases. While the GRF analysis detected clinically relevant SIs in all five dogs with misaligned quadriceps mechanism of the operated limb, the owners perceived excellent, very good and good overall outcomes in three (60%), one (20%) and one (20%) dogs, respectively. Therefore, the dogs had a relatively positive final outcome from the owner's perspective regardless of the MPR. The results of the CBPI might suggest that residual MPR is not relevant to the owners because of the lack of any perception of lameness, although GRF analysis demonstrates that residual luxation impacts the correct use of the limb. However, a misaligned quadriceps mechanism is likely not sufficient to explain the residual lameness detected by GRF in all the dogs, as dog no. 10 had a clinically relevant lower PFz (%TF) and IFz (%TF) on the operated limb with grade I MPR despite the non-operated hindlimb having a grade III MPL (and the owner reported very good final outcome). Similarly, dog no. 14, which had a grade II lateral patellar luxation at follow-up, also had a clinically relevant lower PFz (%TF) and IFz (%TF) on the operated limb compared to the non-operated contralateral limb with grade III MPL. Furthermore, the owner of this patient reported an excellent outcome, which might be due to the inherent owner bias of the CBPI tool. However, in a prospective study, one could evaluate the patient before the surgery and at given intervals after the surgery using the CBPI tool.

The limitations of our study, including its retrospective nature and small sample size, should be considered when interpreting the findings. Despite a review of our institution's medical database revealing 197 dogs treated with either TWR or TBR for MPL, most were lost to follow-up due to the owners' contact details being outdated or owners being unwilling to participate in the study. Furthermore, a relatively large proportion was excluded due to the development of other stifle conditions, such as cranial cruciate ligament tears, to limit their influence on the observed outcome measures. Due to the small sample size and variability of preoperative findings within the groups, we have limited statistical evaluation of our results to descriptive statistics only.

A larger-scale randomised prospective study utilising control groups bilaterally affected by the same grade of MPL and receiving different trochleoplasties for each stifle is required to assess the superiority of TWR or TBR.

CONCLUSION

In conclusion, surgical treatment of grade I–III MPL in dogs weighing less than 10 kg using a combination of either TWR or TBR with additional procedures, such as TTT, anti-rotational sutures and soft tissue procedures, has a favourable overall prognosis. The owners reported good to excellent overall outcomes in 95% of cases. Fifteen percent of dogs showed intermittent grade II lameness.[16] Mean OAS increased in all groups of patients. Kinetic gait analysis helped to identify a substantial proportion of dogs with clinically relevant SIs but no evidence of clinically observed lameness. MPR occurred only in TWR cases. However, a larger-scale prospective study would be required to assess the superiority of TWR or TBR.

AUTHOR CONTRIBUTIONS

Jakub Vodnarek contributed to the conception and design of the study, was responsible for the data acquisition and analysis of the data and was primarily responsible for writing the manuscript. Eva Schneider contributed to the conception of the study and revised the manuscript. Barbara Bockstahler contributed to the study design, data acquisition and revised the manuscript. Eva Schnabl-Feichter contributed to the conception and design of the study and revised the manuscript.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Physical Rehabilitation and the Department of Diagnostic Imaging for their help with the follow-up examinations, and the owners of the dogs for their willingness to participate in the study. The Clinical Unit of Small Animal Surgery of VetmedUni Vienna sponsored the follow-up examinations. No other funding was received.

CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article. The datasets used and analysed during the study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was approved by the Institutional Ethics and Animal Welfare Committee and followed Good Scientific Practice guidelines and national legislation (reference number: ETK-14/02/2021). Owners of all the animals provided informed consent for participation in the study.

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How to cite this article: Vodnarek J, Schneider E, Bockstahler B, Schnabl-Feichter E. Outcome of surgical correction of medial patellar luxation in dogs weighing less than 10 kg. Vet Rec. 2024;e3994. https://doi.org/10.1002/vetr.3994