Medial patellar luxation is one of the most common orthopedic conditions affecting dogs. The nature of the luxation is classified by means of a 4-grade system, and affected dogs have a spectrum of anatomic abnormalities. The most severe form of MPL, classified as grade IV luxation, is characterized by permanent patellar luxation that cannot be reduced with manual pressure. Skeletal abnormalities such as coxa vara, coxa valga, distal femoral varus, hypoplastic trochlear ridges, medial femoral condylar hypoplasia, tibial varus, and torsion can be associated with MPL and may be more common in dogs with grade IV MPL than in dogs with lower-grade MPL. Dogs with grade IV MPL are at higher risk of CCL rupture than dogs with lower-grade luxation, likely because of the chronic internal tibial rotation and increased ligament strain.

Surgical intervention is often recommended for dogs with MPL to ameliorate pain and lameness. A strong correlation reportedly exists between risk of complications and increasing grade of MPL as well as an association between severity of patellar luxation and number of corrective procedures required. A higher rate of MPL recurrence and worse outcomes have been reported for Pomeranians undergoing surgical correction of grade IV MPL, compared with the rate for dogs with lower-grade luxation. To the authors’ knowledge, no studies have been conducted to specifically evaluate outcomes and complications following grade IV MPL correction in a broader population of dogs. The purpose of the study reported here was to determine the complications and short- and long-term outcomes for dogs that underwent surgi-
ocal correction of grade IV MPL. We hypothesized that surgical treatment of grade IV MPL would result in improved limb function, a high rate of owner satisfaction, and an overall successful outcome but would also have a high rate of postoperative complications.

**Materials and Methods**

**Case selection**

Medical records of all dogs with MPL that were brought to the University of Florida Small Animal Hospital and underwent surgery between March 2008 and April 2014 were examined. Dogs were included in the study when they underwent surgical correction of a grade IV MPL. Dogs with grade I, II, or III MPL; lateral patellar luxation; or grade IV MPL that was not treated surgically were excluded. Dogs that did not return for a follow-up evaluation, including radiography, at least 3 months after surgery were also excluded.

**Medical records review**

Medical records were reviewed to collect information on each dog's breed, sex, body weight, date of surgery, and age at time of surgery. Information was recorded regarding the affected limb, the presence and grade of concurrent contralateral MPL, and all surgical procedures and implants involved, including surgical correction of an ipsilateral concurrent CCL insufficiency, when performed. Coronal plane femoral angles were measured from radiographs obtained before and after surgery. The aLDFA, anatomic lateral proximal femoral angle, mL DFA, and mechanical lateral proximal femoral angle were measured for each affected limb as described elsewhere. A single observer (AED) measured all radiographic angles.

Procedures performed, intra- and postoperative complications, and any surgical revisions were recorded. Complications were categorized as minor (not requiring additional surgical or medical treatment to resolve), major (complication or associated adverse effects requiring further surgical or medical treatment), and catastrophic (complication or associated adverse effects that caused permanent unacceptable impairment of function, was directly related to death, or prompted euthanasia) as defined elsewhere, with the exception that pin migration requiring removal with the dog sedated was classified as a minor complication. For analytic purposes, recurrent MPL was classified as a major complication only when a surgical revision requiring general anesthesia was performed, a surgical revision was recommended but declined by the owner, or a grade IV MPL recurred. Additionally, a stifle joint with recurrent MPL and an outcome defined as unsuccessful on follow-up evaluation was classified as a major complication. Revision was defined as a surgical procedure performed at the anatomic site of the original surgery. The grade of any postoperative patellar luxation was also recorded.

**Follow-up evaluation**

As part of the original case management, owners had been contacted and asked to return their dogs to the teaching hospital for follow-up evaluation. The follow-up interval was categorized as long term (> 12 months after the initial surgery), medium term (6 to 12 months), or short term (3 to 6 months). Orthopedic examination and radiography were performed, when possible, and dog owners completed a questionnaire regarding their perceptions of their dog's degrees of postoperative pain, function, and quality of life.

A board-certified surgeon performed each orthopedic examination. Presence and grade of MPL were recorded as well as presence or absence of joint effusion, muscle atrophy, crepitus, CCL instability, a so-called medial buttress, and signs of pain on joint palpation. Lameness evaluations were performed while the dog was standing, walking, and trotting by use of a published 5-point scale (0 = no observable lameness; 1 = intermittent mild weight-bearing lameness with little, if any, change in gait; 2 = consistent mild weight-bearing lameness with little change in gait; 3 = moderate weight-bearing lameness [obvious lameness with noticeable change in gait]; 4 = severe weight-bearing lameness [toe-touching lameness only]; 5 = non-weight-bearing lameness).

The questionnaire that owners were asked to complete prompted them to rate their dog's signs of pain on a scale from 0 to 10, in which 0 indicated no pain and 10 indicated extreme pain (Supplemental Appendix S1, available at http://avmajournals.avma.org/doi/suppl/10.2460/javma.249.2.208). Owners were also asked to evaluate the degree to which their dog's discomfort appeared to interfere with its daily life (eg, walking, running, or rising to standing) on a scale from 0 to 10, in which 0 indicated no interference and 10 indicated complete interference. Owners were then asked to score their dog's overall condition, attitude, mood, and playfulness and indicate whether these characteristics had improved, worsened, or remained the same since surgery. Finally, owners were asked to choose between unacceptable, acceptable, and full when describing their dog's postoperative return to function.

On the basis of complication severity, owner questionnaire responses, and surgeon evaluations, stifle joints were categorized as having an overall successful or unsuccessful outcome. For this purpose, a successful outcome was defined as one in which the stifle joint was free of catastrophic complications and the dog was described by the owner as having full or acceptable postoperative return to function and for which its signs of pain and lameness at follow-up were scored by the owner as < 3 and by the surgeon as < 2. An unsuccessful outcome was defined as any stifle joint not meeting the criteria for a successful outcome. Stifle joints that underwent revision surgery that subsequently failed or for which owners declined revision surgery when recommended were also defined as having an unsuccessful outcome.

**Statistical analysis**

Collected data were analyzed in 2 stages. For stifle joints from the same dog, 1 stifle joint was arbitrarily selected for inclusion in statistical analysis (n = 24).
to avoid correlated observations. First, data were examined for quality with summary statistics appropriate for their type: means (or medians) with SDs for continuous variables and distributions for categorical variables (such as sex or breed). Second, to investigate potential risk factors for MPL complications, ORs (with 95% confidence intervals) were calculated for associations with each outcome. Odds ratios that were statistically different from 1 were considered significant. Other comparisons of categorical data were made with the Fisher exact test, with values of \( P \leq 0.05 \) considered significant.

Results

Dogs

Twenty-nine stifle joints (15 left and 14 right) of 24 dogs met the criteria for inclusion in the study. Fifteen dogs were male (9 castrated and 6 sexually intact), and 9 were female (7 spayed and 2 sexually intact). Body weight at the time of surgery ranged from 1.5 to 40.0 kg (3.3 to 88 lb; mean ± SD, 15.3 ± 13.0 kg [33.7 ± 28.6 lb]). Age at the time of surgery ranged from 2 months to 10.0 years (mean, 2.6 ± 2.7 years). Sixteen of the 24 (67%) dogs had concurrent contralateral MPL (2 with grade I, 2 with grade II, 5 with grade III, and 7 with grade IV).

Surgical methods

Tibial tuberosity transposition was performed on 26 of 29 (90%) stifle joints. Femoral trochlear sulcoplasty was performed on 25 (86%) stifle joints. Techniques used to improve femoral trochlear depth included wedge trochleoplasty (n = 11 [38%]), block trochleoplasty (11 [38%]), and abrasion trochleoplasty (3 [10%]). Medial fascial release was performed on 25 (86%) stifle joints, and lateral imbrication was performed on 27 (93%). Extracapsular anterotational sutures were used on 4 (14%) stifle joints. Femoral corrective osteotomy was performed on 22 (76%) stifle joints, and tibial corrective osteotomy was performed on 4 (14%). No dogs with bilateral grade IV MPL underwent a single-stage bilateral procedure. Number of individual procedures performed per stifle joint ranged from 3 to 7 and was not significantly (\( P = 0.42 \)) associated with postoperative complications.

Twenty-three (79%) stifle joints had an intact CCL at the time of initial surgery. Of the 6 (21%) stifle joints with CCL insufficiency, 2 were treated by tibial plateau leveling osteotomy and 4 were stabilized with a lateral fabellar suture. For dogs that underwent tibial plateau leveling osteotomy, the tibial osteotomy was modified by translating the distal segment laterally rather than use of tibial tuberosity transposition for tibial realignment.12

Femoral angles

Mean preoperative aLDFA and mLDFA for stifle joints that underwent femoral correction were 111.4° and 119.8°, respectively (reference range for aLDFA, 93.2° to 98.5°; for mLDFA, 96.6° to 101.0°). The mean aLDFA and mLDFA for those that did not undergo femoral correction were 106.2° and 94.8°, respectively. For dogs that underwent femoral correction, the mean postoperative aLDFA and mLDFA were 93.6° and 96.3°, respectively.

Preoperative values for mLDFA or aLDFA did not significantly correspond with whether dogs underwent femoral correction (\( P = 0.40 \) for both) or had a recurrence of MPL (\( P = 1.00 \) for both). Postoperative values for the same variables did not significantly (\( P = 1.00 \) for both) correspond with recurrence of MPL.

Postoperative complications

Sixteen (55%) stifle joints developed postoperative complications; no complications developed in the other 13 (45%) joints. Minor complications developed for 8 of 29 (28%) joints, and major complications developed for 7 (24%) joints (Table 1). Plate and intramedullary pin failure occurred at the femoral osteotomy site, eventually leading to limb amputation, in a 1.5-kg Yorkshire Terrier, and this was considered a catastrophic complication (1/29 [3%]). Surgical revision was performed on 6 (21%) stifle joints.

Age at the time of surgery was significantly associated with development of major postoperative complications (OR, 1.9; 95% confidence interval, 1.2 to 4.6). No significant associations with major postoperative complications were identified for body weight, presence of concurrent contralateral MPL, presence of ipsilateral CCL insufficiency, total number of procedures performed at the first surgery, or use of femoral corrective osteotomy.

Recurrent MPL

At the short-term follow-up examination, MPL had resolved in 21 of 29 (72%) joints and 8 (28%) joints had continued MPL (grade I, n = 5; grade II, 1; grade III, 1; and grade IV, 1). Five of the 10 stifle joints that received a long-term follow-up evaluation had recur-

Table 1—Number (%) of stifle joints in which complications developed following surgical correction of grade IV MPL (n = 29 joints of 24 dogs).

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%) affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td></td>
</tr>
<tr>
<td>Edema of the tibiotarsal (hock) joint</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Screw fracture requiring no further surgery</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Incisional redness</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Patellar tendonitis necessitating Kirschner wire removal</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Implant migration necessitating Kirschner wire removal</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Vomiting secondary to NSAID use</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Major</td>
<td></td>
</tr>
<tr>
<td>Recurrent MPL resulting in a second surgery</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Tibial tuberosity avulsion fracture</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Fracture through jig hole of tibial plateau osteotomy</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Pin and tension band excision</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Implant failure</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Catastrophic</td>
<td></td>
</tr>
<tr>
<td>Femoral fracture resulting in limb amputation</td>
<td>1 (3)</td>
</tr>
</tbody>
</table>
rence of MPL (grade I, 1; grade II, 1; and grade III, 3). Overall proportion of stifle joints with recurrence of MPL was 38% (11/29; grade I, 5; grade II, 1; grade III, 4; and grade IV, 1). Recurrence of MPL did not significantly ($P = 1.00$) affect short- or long-term functional outcome.

**Outcomes**

All 24 dogs (29 stifle joints) were brought to the veterinary teaching hospital for a 3-month postoperative follow-up evaluation. Information regarding 8 (28%) stifle joints was lost to follow-up when that follow-up occurred > 3 months after the original surgery. Owners of 3 dogs (4 joints) could not be reached by telephone or email, and owners of another 3 dogs (4 joints) declined a follow-up examination or questionnaire completion for unspecified reasons. One dog for which follow-up information had been obtained was the Yorkshire Terrier that had been classified as having a catastrophic complication because of implant failure and eventual limb amputation at 4 months after the original surgery. Of the remaining 20 stifles joints that received a follow-up examination > 3 months after surgery, 3 (15%) joints received a short-term (3 to 6 months after surgery) follow-up evaluation, 1 (5%) joint received a medium-term (6 to 12 months after surgery) evaluation, and 16 (80%) received a long-term (> 12 months after surgery) evaluation that included a questionnaire with or without additional examination or radiography.

Eight of 24 (33%) dogs (10/29 [34%] stifle joints) returned for long-term follow-up evaluation and radiography. Five of the 10 joints had evidence of recurrent MPL at that evaluation (grade I, n = 1; grade II, 1; and grade III, 3). Six of the 10 joints were assigned a lameness score of 1 (intermittent mild weight-bearing lameness) by an orthopedic surgeon, 3 were assigned a lameness score of 0 (no lameness), and 1 was assigned a lameness score of 2 (consistent mild weight-bearing lameness). Eight stifle joints were assigned a pain score of 0 by the orthopedic surgeon, 1 was assigned a pain score of 1, 1 was assigned a pain score of 2, and none received a pain score ≥ 3.

Owners of 17 dogs (representing 20 stifle joints) completed a follow-up questionnaire, and 14 of these owners (representing 16 stifle joints) were considered to have completed a long-term follow-up owner evaluation. For those responding to a long-term follow-up questionnaire, owners of 7 dogs (representing 7 stifle joints) reported their dog’s postoperative return to function as full, and owners of another 7 dogs (9 stifle joints) categorized their dog’s return to function as acceptable. No owners reported return to function as unacceptable. Owners of 9 dogs (representing 9 stifle joints) reported that their dog had an increase in activity following surgery, whereas owners of 5 dogs (7 stifle joints) reported no change in activity.

Overall, 27 of 29 (93%) joints met the criteria for a successful outcome. Two (7%) joints were assigned an unsuccessful outcome. The dog associated with one of these joints was assigned a pain score of 4 of 10 by its owner (this dog had a tibial tuberosity avulsion fracture 4 weeks after surgery). The dog associated with the other joint was the Yorkshire Terrier with the catastrophic complication resulting in amputation. Of the 16 stifle joints for which long-term follow-up information was obtained via physical examination, questionnaire, or both, 15 were classified as having a successful outcome, and 1 was classified as having an unsuccessful outcome (owner-assigned pain score of > 3).

**Discussion**

In the study reported here, 24% (7/29) of stifle joints in dogs that underwent surgical correction for grade IV MPL developed major complications. The overall proportion requiring surgical revision was 21%, and the overall proportion with recurrence of MPL within a 6-month follow-up period was the same. Despite these high proportions, 93% of stifle joints had a successful outcome, defined as a full or acceptable outcome as judged by the owner and minimal pain and lameness as judged by the owner and surgeon.

The proportion of stifle joints that developed major postsurgical complications was higher than that in other studies in which all MPL grades were included. A major complication rate of 13% was identified in a retrospective study involving 131 patellar luxation corrections, and a rate of 18% was identified in another study involving 124 such corrections.

Results of the present study can be ascribed to the complexity of the included cases. Several dogs had complex osseous deformities requiring bi- or multiaxial corrective ostectomy, limited anatomic dimensions (body weight < 2 kg [4.4 lb]), or concurrent CCL insufficiency. As suggested by other investigators, correction of grade IV MPL is more difficult to perform and has a greater risk of postoperative complications than correction of lower-grade MPL.

Most dogs that underwent surgical treatment of grade IV MPL in the present study had good return to function and high rates of owner satisfaction and clinical success, despite a higher complication rate than previously reported. We were unable to identify predictors of outcome (good return to function, high rates of owner satisfaction, and good clinical success) because of the small number of dogs with poor or unacceptable outcomes. It is important to note that the 2 dogs that did not obtain full return to function after surgery (ie, had an unsuccessful outcome as defined by the surgeon or owner) had major or catastrophic complications, corroborating findings of other studies in which surgical complications had a significant impact on functional outcome. In contrast, recurrence of MPL did not influence outcomes in the study reported here, calling into question the clinical implications of residual, lower-grade, postoperative MPL. The proportion of joints with recurrence of MPL was higher than previously reported but was not unexpected given our inclusion of joints with grade IV MPL only.
In the present study, femoral corrective osteotomy was performed for 86% of stifle joints. The decision to perform a femoral corrective osteotomy for correction of MPL in dogs remains controversial, although an aLDFA ≥ 102° or a femoral varus angle ≥ 12° has been proposed as an objective criterion for electing to perform femoral corrective osteotomy. Radiographic measurement of aLDFA was repeatable and reproducible but with low statistical accuracy for measurement of femoral varus in an ex vivo study. For the dogs of the present study, the decision to perform femoral corrective osteotomy was based on a combination of criteria, including excessive femoral varus (aLDFA ≥ 102° or femoral varus angle ≥ 12°), owner willingness, and projected postoperative owner compliance. The variability in these criteria, even among surgeons at a single institution, may explain the lack of correspondence between preoperative aLDFA values and whether a dog was treated with femoral corrective osteotomy.

No statistical association was identified in the present study between recurrent MPL and corrective femoral osteotomy, nor were we able to demonstrate that postoperative mLDFA influenced the rate of complications or recurrence of MPL. These findings should be interpreted cautiously, given that corrective femoral osteotomy was performed for 86% of stifle joints, some for complex biapical femoral deformities and some in conjunction with tibial corrective osteotomies. Previous studies have shown that a low varus angle is important following surgical correction of grade IV MPL, and femoral corrective osteotomy was performed in the present case series with reasonable success rates. Therefore, femoral corrective osteotomy might be considered as a component of MPL repair for a dog with severe femoral varus.

Increasing age was found to be a risk factor for development of a major postoperative complication in the dogs of the present study. This finding was not unexpected because immature dogs have a larger potential for soft tissue adaptation than do adult dogs. Older dogs with grade IV MPL are likely to have a greater degree of perarticular fibrosis secondary to the abnormal conformation and alignment of the quadriceps mechanism, compared with findings in younger dogs with grade IV MPL. Additionally, dogs with severe femoral and tibial deformities often have soft tissue abnormalities such as shortening of the quadriceps mechanism. The age-related increase in fibrosis and subsequent decrease in soft tissue compliance likely contributed to the increased risk of complication in dogs with grade IV MPL.

Long-term follow-up evaluation (> 12 months after surgery) was performed for 16 stifle joints in the present study, although only 8 dogs (10 stifle joints) returned for orthopedic follow-up examinations. All owners of dogs for which long-term follow-up information was obtained reported that their dog had full or acceptable function. One dog had an owner-assigned pain score of 4 (higher than the cutoff of 3 used to define a successful outcome, and classified as an unsuccessful outcome overall), but the owner also categorized the dog as having an acceptable return to function. That same dog was identified as mildly lame, but without signs of pain, by the surgeon at the follow-up examination. These findings corroborated those of previous studies in which owner perception of pain and function did not correspond with orthopedic examination findings. These inconsistencies could be attributable to owner misperception of the dog’s degree of comfort or low sensitivity of a surgeon’s orthopedic examination versus daily owner observation.

Limitations of the study reported here included its retrospective nature, variability in surgical technique and decision making, subjectivity of owner responses to the follow-up questionnaire, and small sample size, which made it difficult to identify risk factors for development of postoperative complications and could have contributed to misleading results. Although 29 stifle joints qualified for inclusion in the study, the owner questionnaire was completed for only 20 stifle joints (17 dogs), and 10 stifle joints (8 dogs) received a follow-up orthopedic and radiographic examination > 12 months after surgery, limiting the statistical power for evaluation of long-term follow-up data. Additional studies involving multiple institutions to increase the number of included dogs and joints are warranted. Regardless of these limitations, the present study revealed that surgical correction of grade IV MPL in dogs had a favorable overall success rate but that postoperative complications necessitating revision surgery were common.

**Acknowledgments**


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**References**

9. Cook JL, Evans R, Conzemius MG, et al. Proposed definitions and criteria for reporting time frame, outcome, and complica-


