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**Objective**—To determine long-term outcome of distal femoral osteotomy as a component of treatment for distal femoral varus and medial patellar luxation in large-breed dogs.

**Design**—Retrospective case series.

**Animals**—12 dogs (16 stifle joints).

**Procedures**—Medical records and radiographs were reviewed to identify large-breed dogs with medial patellar luxation (grade ≥ 2) and femoral varus angle ≥ 12° treated with distal femoral osteotomy, with a minimum follow-up (by a veterinarian) of 18 months. Signalment, weight, medial patellar luxation and lameness grade, pre- and postoperative femoral varus angle, surgical technique, time to radiographic bone union, and complications were recorded. Follow-up with owners via questionnaire was performed >18 months after surgery.

**Results**—16 corrective distal femoral osteotomies were performed with ancillary medial patellar luxation procedures in 12 dogs; 4 dogs had staged bilateral procedures. Mean ± SD preoperative and postoperative femoral varus angles were 16.3 ± 4.3° and 3.9 ± 2.5°, respectively. Mean ± SD time to radiographic union of the distal femoral osteotomy was 52.6 ± 13 days. One dog had Kirschner wire migration from the tibial tuberosity. Patellar luxation was not detected after surgery in any dog. Mean ± SD follow-up by a veterinarian was 1,335 ± 410 days and by use of an owner questionnaire was 1,497 ± 464 days. All 10 variables of owner-observed patient comfort and function were significantly improved.

**Conclusions and Clinical Relevance**—Distal femoral osteotomy in combination with traditional treatment provided predictable osteotomy healing, patellar stabilization, and long-term improvement in patient comfort and function when used to treat combined distal femoral varus and medial patellar luxation in large-breed dogs. (J Am Vet Med Assoc 2007;231:1070–1075)

Medial patellar luxation is the most common congenital abnormality in dogs, affecting >7% of pups in 1 study.¹ Medical patellar luxation occurs most frequently in small-breed dogs; however, the prevalence of medial patellar luxation in large-breed dogs is apparently increasing.²⁻⁴ Medical patellar luxation is often present bilaterally and frequently causes lameness, progressive cartilage wear, and osteoarthritis and may contribute to cranial cruciate ligament degeneration in dogs.³⁻⁶

Proper anatomic alignment of the quadriceps-patellar mechanism with the underlying skeleton promotes normal patellar tracking.⁷ The patella is constrained by the surrounding joint capsule, retinaculum, and medially-lateral femoropatellar ligaments; the balanced tension combines with normal patellofemoral joint conformation to maintain normal patellar position. In instances of medial patellar luxation, early restoration of normal quadriceps-patellar mechanical function through correction of underlying conformational abnormalities should improve patient comfort and function and minimize abnormal cartilage wear and associated clinical signs.³

Classically, the 2 skeletal conformations most commonly identified and treated are a shallow trochlear sulcus and medial displacement of the tibial tuberosity. These abnormalities may be corrected surgically with trocholeoplasty and tibial crest transposition, respectively. Additionally, soft tissue reconstructive procedures such as lateral joint capsule imbrication and medial release of the joint capsule, retinaculum or the quadriceps muscle group are often required to balance the medial and lateral tensile forces exerted on the patella.⁹ Treatment of medial patellar luxation can be costly and time-consuming and may cause considerable perioperative discomfort and disability, especially if revisions are necessary. The rate of patellar reluxation following these traditional surgical treatments ranges from 8% to 50% and is more common in large-breed than in small-breed dogs.³⁻⁸⁻⁹

Excessive femoral varus conformation has been implicated in the pathogenesis of medial patellar luxation.⁵⁻⁷,⁻¹⁰⁻¹¹,ᵃ Only recently have efforts been made to measure, document, and treat femoral varus when combined with medial patellar luxation.¹¹,ᵃ Perkuski et al² reported postoperative outcomes of distal femoral osteotomy in a research abstract, but the length of follow-up and assessment of patient comfort and function were not included. The aim of the study reported here was to determine the long-term veterinarian- and owner-observed patient outcome (>18 months) of distal femoral osteotomy as a component of surgical treatment.
for combined distal femoral varus and medial patellar luxation in large-breed dogs. We hypothesized that distal femoral osteotomy in combination with indicated traditional surgical medial patellar luxation treatments would provide predictable osteotomy healing, patellar stabilization, and long-term improvement in patient comfort and function.

Criteria for Selection of Cases

Medical records and radiographs of the Mobile Veterinary Surgical Group (Aptos, Calif) and its referring practices were reviewed to identify dogs treated with distal femoral osteotomy in conjunction with traditional repair of medial patellar luxation between November 1999 and May 2004 by one of the authors (RHP). Dogs were included if they weighed ≥ 18 kg (40 lb), had lameness associated with medial patellar luxation ≥ grade 2,12 had femoral varus angle ≥ 12° as measured from radiographs,11 and were treated with distal femoral osteotomy as a component of their medial patellar luxation repair.13 Dogs were excluded from the study if the follow-up time via either recorded veterinary examination or pet-owner questionnaire was < 18 months.

Procedures

Recorded data included signalment, body weight, medial patellar luxation grade, lameness grade, preoperative and postoperative femoral varus angle, surgical findings and technique, time to radiographic bone union, assessment of radiographic progression of osteoarthritis, and complications. Patient positioning for radiography, criteria for acceptability of radiographs, measurement of femoral varus angle from radiographs, presurgical planning, surgical technique, and recommended postoperative care for distal femoral osteotomy were performed by 1 person (RHP) by use of methods described elsewhere.11,13 Briefly, all corrective distal femoral osteotomies were performed by use of a laterally based, closing-wedge osteotomy with the intraoperative aid of an alignment jig.9 The distal femoral osteotomies were stabilized with a bone plate and screws placed on the lateral surface of the femur. Various ancillary procedures for augmentation of patellar stabilization were performed as deemed necessary by the surgeon.

Long-term outcome—Long-term outcome was assessed by review of all available postoperative radiographs and recorded veterinary examination findings (board-certified veterinary surgeon, referring veterinarian, or both) following surgery and by use of a validated owner questionnaire. Pre- and postoperative lameness descriptions were converted to a 5-point grading scale (Appendix). Repeatability and validation of the visual analogue scale owner questionnaire used in this study7 have been established for assessment of mild-to-moderate lameness in dogs with force platform gait analysis as the criterion standard.14 Questionnaires were completed in December 2005 by each dog owner regarding their dogs comfort and function at 3 periods relative to surgery, including the preoperative period, time of full recovery, and time of the study (termed the current period). Dog owners were instructed that the preoperative period questions referred to the period immediately prior to surgery (owners of dogs that had staged distal femoral osteotomy procedures on each limb were instructed that preoperative questions referred to the period prior to surgery on the first limb treated via surgery). Dog owners were instructed that the full recovery period questions referred to the period after surgery when their dog first exhibited maximal comfort and limb use (owners of dogs that had staged distal femoral osteotomy surgeries on each limb were instructed that full recovery period questions referred to the period after the procedure on the second limb). Dog owners were instructed that the current period questions referred to the month prior to completion of the questionnaire. The visual analogue scale was formatted to have a 10-cm horizontal line with vertical marks on each end. The vertical mark on the left end of the line correlated to a negative response to the question asked, and the vertical mark on the right end of the line correlated to a positive response to the question asked.14 Owners were asked to record with a vertical mark on the appropriate visual analogue scale their observations of 10 variables of their dogs comfort and function: activity, attitude, mood, frequency of comfort postures (evidence that the dog appeared happy), willingness to play voluntarily, frequency of exercise, degree of morning stiffness, degree of evening stiffness, frequency of lameness at a walk, and frequency of pain when turning. Each response was measured to the nearest tenth of a centimeter.

Statistical analysis—For each question on the questionnaire, the change in response between each of the periods (preoperative, full recovery, and current) was evaluated by use of a repeated-measures analysis. For these evaluations, P < 0.05 was considered significant. Review of the raw data revealed that 1 owner responded 0 to all preoperative questions and 10 to all postoperative (full recovery and current) questions. This observation suggested that this owner did not critically evaluate each question prior to answering. To avoid statistical bias from this owner’s responses, these data were excluded from further analysis. Owners assessed the overall outcome of surgery at the full recovery and current periods; results are reported as mean ± SD on a 10-point scale. All other results are reported as mean ± SD unless otherwise specified.

Results

Review of the medical records revealed 15 dogs that met inclusion criteria. Of these dogs, follow-up > 18 months via veterinary examination and the owner questionnaire was not available for 3 dogs; 2 owners could not be contacted, and 1 dog had been killed by an automobile. Of the remaining 12 dogs, 8 had unilateral surgery and 4 had staged bilateral surgery (total, 16 surgeries).

Signalment and preoperative clinical findings—Age at surgery was 19.8 ± 7.5 months (range, 12 to 42 months), and there were 7 spayed females, 5 neutered males, 3 Labrador Retrievers, 2 Pit Bull Terriers, 1 Border Collie, 1 Airedale Terrier, and 5 mixed-breed dogs. Body weight was 31.9 ± 7.8 kg (70.3 ± 17.2 lb) with a range of 20 to 48 kg (43 to 106 lb). Grade 2 medial patellar luxation was detected in 3 of the operated stifle joints, and grade 3 medial patellar luxation was detected in the remaining 13 operated stifle joints. Bilateral medial patellar luxation was detected in 6 of 11 dogs; the status of the patella in the opposite limb was not recorded for 1 dog. Two dogs with bilateral medial patellar luxation only received surgical treatment on 1 stifle joint.

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Surgical findings and procedures—Preoperative femoral varus angle for operated stifle joints was 16.3 ± 4.3° (range, 12 to 29). Postoperative femoral varus angle was 3.9 ± 2.5° (range, 0 to 8). Ancillary procedures performed in addition to distal femoral ostectomy (depending on surgeon assessment of each dog’s needs for correction of the medial patellar luxation) included 1 or more of the following: trochleoplasty (n = 7 joints), tibial tuberosity transposition (4), medial release (10), and lateral imbrication (15). Cranial cruciate ligament damage (mild edema along the caudolateral edge) was detected in 1 dog but did not require specific treatment. One dog that satisfied the inclusion criteria had a complete cranial cruciate ligament tear and was treated with concurrent tibial plateau leveling ostectomy, but was excluded from the study because of lack of long-term follow-up.

Radiographic evaluation—Concurrent canine hip dysplasia was detected before surgery in 5 dogs and was mild in 2 dogs, moderate in 1 dog, and severe in 2 dogs. Radiographic bony union of the distal femoral ostectomy was confirmed in all 16 procedures. Timing of radiography relative to surgery did not allow an estimate of the time required for bony union in 5 procedures. Time to union of 52.6 ± 13 days (range, 30 to 76) was determined from radiographs of the remaining 11 procedures. Migration of the Kirschner wires used to secure a tibial crest transposition was detected in 1 dog. Postoperative patellar luxation was not detected on radiographs in any dog. Radiographic follow-up > 1 year (mean, 643 days; range, 394 to 975) was available for 3 of the operated stifle joints. Minimal osteophytosis and stifle joint effusion with no progression were evident in 2 dogs and progression from mild preoperative to moderate postoperative osteophytosis and effusion was evident in 1 dog at 560 days.

Veterinary examination—Follow-up time between surgery and the last veterinary examination was 1,335 ± 410 days (range, 718 to 2,107). Preoperative lameness grade was 3.11 ± 1.0 (range, 2 to 5). Postoperative lameness grade was 0.5 ± 1.1 (range, 0 to 3); the grade 3 lameness was an isolated episode recorded in 1 dog 25 months after surgery. The lameness grade of all dogs improved from the preoperative period to each of the postoperative periods in 79% (87/110) of the variables. Improvement was measured from the preoperative period to only one of the postoperative periods (either the full recovery period or the current period) in 14% (15/110) of the variables. There was worsening from the preoperative period to each of the postoperative periods in 7% (8/110) of the variables, most of which were in dogs with bilateral medial patellar luxation (7/8 dogs).

The overall change in responses between periods for each of the questions was analyzed (Figure 2). Significant visual analogue scale scores were graphically summarized (Figure 1). Raw data revealed improvement from the preoperative period to each of the postoperative periods in 79% (87/110) of the variables. Improvement was measured from the preoperative period to only one of the postoperative periods (either the full recovery period or the current period) in 14% (15/110) of the variables. There was worsening from the preoperative period to each of the postoperative periods in 7% (8/110) of the variables, most of which were in dogs with bilateral medial patellar luxation (7/8 dogs).

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Corrective distal femoral osteotomy has been advocated as a component of surgical correction of medial patellar luxation when complicated by excessive femoral varus. The point at which femoral varus is excessive and distal femoral osteotomy should be performed is unclear, but ≥ 12° was used as the criterion for this report because it is outside the reference range reported to date. Before we began to offer distal femoral osteotomy in 1999, subjective clinical experience suggested that patellar relaxation following traditional surgical treatment for medial patellar luxation was more frequent in large-breed dogs than in small-breed dogs, which was recently confirmed by Arthurs and Langley-Hobbs. This led to speculation that untreated excessive femoral varus may play a role in postoperative patellar relaxation following traditional treatment for medial patellar luxation in large-breed dogs. At the time we performed the distal femoral osteotomies reported herein, there were no published reports of femoral varus measurement in clinically normal dogs or dogs with medial patellar luxation from which to base the definition of excessive. Given the paucity of data upon which to advise treatment, we made our treatment recommendations on the basis of our best understanding of distal femoral varus and medial patellar luxation in large-breed dogs from reports of femur conformation. First, a femoral varus angle ≥ 10° had been theorized to increase rotational force at the stifle joint. Additionally, an anatomic study revealed that the intercondylar fossa of clinically normal mixed-breed dogs deviated approximately 7° from the sagittal plane of the femoral diaphysis. The similarity of our preoperative femoral varus angle values to those reported by Peruski et al suggests that the selection criterion of ≥ 12° used in the present study was similar to that used by others.

Femoral varus measurement from radiographs of clinically normal dogs has only recently been reported; the groups of dogs studied included a variety of breeds. We concur with others who speculate that the normal amount of femoral varus likely varies among breeds. As methods of femoral varus measurement are validated, future studies to develop breed-specific profiles of femoral varus in clinically normal dogs and those with medial patellar luxation will aid in developing more stringent criteria for performing distal femoral osteotomy. Dudley et al confirmed the accuracy of femoral varus angle measurement from radiographs by comparison with measurements obtained directly from isolated specimens. A related standardized method of radiographic measurement of varus and valgus angles was recently adapted from humans to dogs, but to the authors’ knowledge, it has not yet been validated for use in dogs by comparison with direct anatomic measurements. In the present study, 1 person performed all patient positioning for radiographs to ensure consistency. Occasionally, restricted range of motion of the hip joints caused by hip dysplasia or heavy muscle mass required use of a torso-elevated, hip-extended radiograph to place the femora perpendicular to the radiographic beam. Artifactual radiographic evidence of femoral varus is easily created by improper patient positioning, especially external rotation of the hip joint. For this reason, all radiographs were screened for acceptability (femora parallel, parallelism of the walls of the intercondylar notch, fabellae bisected by their respective femoral cortex, and protrusion of the corticocancellous tip of lesser trochanter from the medial femoral cortex). The same person measured the femoral varus angle from acceptable radiographs, and typically, the mean femoral varus angle measured from > 1 radiograph was used. Despite this attention to detail, the possibility of some error in preoperative or postoperative femoral varus angle measurement must be acknowledged.

In dogs with unilateral medial patellar luxation, it is not clear what role, if any, the femoral varus angle of the unaffected limb should have in determining the need for a distal femoral osteotomy or in determining the desired postoperative femoral varus angle. In contrast to the method reported here, perhaps the femoral varus angle of the unaffected limb should serve as the normal value for comparison from which the need for a femoral osteotomy is assessed. When the femoral varus angle is greater in the limb affected by medial patellar luxation, perhaps the ideal postoperative varus angle should be approximate to that of the unaffected limb. By use of these criteria, distal femoral osteotomy would not have been performed or would have resulted in extremely small corrections in at least 4 of 5 dogs with unilateral medial patellar luxation in this study. These conjectures are made with the assumptions that the patellofemoral joints unaffected by medial patellar luxation are biomechanically normal and will not develop patellar luxation in the future; the validity of these assumptions is unknown. Perhaps the absence of patellar luxation in the contralateral stifle joint is attributable to the integrity of patellofemoral stabilizing factors such as the medial and lateral patellofemoral ligaments, shape of the patella, and shape of the trochlear sulcus, rather than being indicative of the lack of mechanical forces favoring patellar luxation. An analogous situation may be cranial tibial thrust constrained by an intact cranial cruciate ligament in a healthy stifle joint. Provided that constraint is intact, tibial plateau leveling osteotomy is not indicated. However, tibial plateau leveling osteotomy is often indicated for treatment of stifle joints in which the cranial cruciate ligament has failed. In that situation, the contralateral stifle joint’s tibial plateau angle is not presently used as
a criterion to assess the need for tibial plateau leveling osteotomy or as a reference for the ideal postoperative tibial plateau angle. Instead, the tibial plateau is leveled to a tibial plateau angle of approximately 5°, a point where the cranial tibial thrust is neutralized and constraint provided by the cranial cruciate ligament is unnecessary.17 Similarly, we theorize that corrective distal femoral osteotomy promotes normal patellar tracking by improving alignment of the femur with the overlying quadriceps muscles, thereby decreasing reliance on patellofemoral constraints that may be abnormal, either as a cause or an effect of medial patellar luxation. The postoperative femoral varus angle values reported here were similar to those reported by Peruski et al.8 The absence of patellar relaxation reported here and by Peruski et al contrasts favorably with the reported 8% to 9% prevalence of postoperative patellar relaxation in large-breed dogs treated by use of traditional surgical techniques without measurement or treatment of femoral varus. These observations lend some support to our mechanical alignment theory. Future study to measure the effects of femoral varus on patellofemoral biomechanics is warranted. Until such biomechanical data are known and breed-specific profiles of femoral varus in clinically normal dogs and dogs with patellar luxation are determined, the selection criteria for distal femoral osteotomy and the ideal postoperative femoral varus angle will remain unclear.

In the study reported here, ancillary procedures for augmentation of patellar stabilization were performed as deemed necessary by the surgeon, similar to that reported elsewhere.4 Others have suggested that trochleoplasty and tibial tuberosity transposition should be performed in large-breed dogs to decrease the prevalence of patellar relaxation.2,5 Failure to perform trochleoplasty or tibial tuberosity transposition when an indication for those procedures was not evident did not seem to adversely affect patellar relaxation or patient outcome in the study reported here.

The absence of noteworthy lesions of the cranial cruciate ligament in these dogs was in contrast to the 6% to 47% frequency of lesions concurrent with or prior to medial patellar luxation that has been reported.2,6,7 It has been theorized that increased internal stifle joint rotation caused by medial patellar luxation may contribute to lesions of the cranial cruciate ligament.3,3 Converesly, the increased internal rotational instability of a stifle joint with cranial cruciate ligament deficiency may predispose to or exacerbate medial patellar luxation.

Healing of the distal femoral osteotomies was predictable and relatively rapid in this series. The femur is well-vascularized through the firm attachment of the adductor muscle along its caudal margin. Preservation of these attachments may explain the absence of delayed union or nonunion of the distal femoral osteotomies. In contrast, Peruski et al5 reported infection necessitating implant removal and delayed healing of distal femoral osteotomies, although the frequency of those complications was not stated.

In the present study, the mean follow-up approached 4 years after surgery. The absence of patellar relaxation and the improvement in lameness scores during this extended follow-up period appear promising.

Surprisingly, little attention has been paid to long-term patient comfort and function following treatment of medial patellar luxation. In 1998, Innes and Barr21 determined that owner assessment of functional outcome of dogs treated for cranial cruciate ligament injury was reliable and repeatable. Client questionnaires and owner assessments have been used in many studies2-27 to evaluate postoperative limb use and function after cranial cruciate ligament surgery. One method of recording owner responses to questions is a visual analogue scale, which is accurate and reliable for evaluating lameness.26 In contrast to many published owner questionnaires, the repeatability and validity of the questionnaire used in the present study for assessing mild-to-moderate lameness in dogs have been established by use of force platform gait analysis as the criterion reference.10

Analysis of the raw data as well as statistical comparison between periods for each owner-observed variable revealed remarkable postoperative improvement in patient comfort and function. In general, improvement was evident from the preoperative period to each of the postoperative periods (full recovery and current), but little change was evident from the full recovery period to the current period. The most substantial improvements following surgery were in patient comfort, signs of pain while turning suddenly, and lameness at a walk. Although this suggests that these are the most important benefits of the procedure, it is possible that these behaviors are more easily assessed and observed by dog owners; therefore, a change in them could be more easily detected, compared with other variables. Regardless, this may be valuable information for dog owners during pretreatment counseling.

The only significant change observed by dog owners between the full recovery and current periods was continued improvement in activity. This suggests that the patient comfort and function observed by dog owners at the time when their dog’s recovery seems to reach a plateau are reasonably good indicators of expected long-term outcome, with few exceptions. Analysis of the raw data suggested that 1 exception may be in the dog’s stiffness.

Initial improvement in a variable followed by worsening was detected in only 5 of 110 observations, but when this worsening was detected, it was most commonly associated with stiffness (3/5 observations). This may have been related to development of osteoarthritis in the stifle joints, hips, or elsewhere. The minimal radiographic progression of stifle joint osteoarthritis in 2 of the 3 dogs for which long-term radiographic follow-up was available was interesting, but the limited numbers precluded the ability to make any definitive conclusions.

Limitations of the study reflected its retrospective design. Accuracy of the data was dependent on the accuracy of the medical records. It is possible that grade 1 medial patellar luxation may not have been detected or recorded. Furthermore, corrective surgeries were tailored for the needs of each dog as deemed appropriate by the surgeon rather than by following a standardized protocol. Likewise, the timing of follow-up examinations and radiography was not standardized. The ab-
sence of a control group prevented direct comparisons of long-term outcomes of a similar population treated with traditional surgical techniques but without concurrent distal femoral osteotomy.

The questionnaire required owners to recall observations in 3 periods and may have permitted recall bias. Recall bias can positively or negatively skew study results. It can obscure therapeutic benefit when subjects become accustomed to improved function or quality of life. This so-called satisfaction treadmill effect occurs when subjects report that the treatment had no effect because the remembered baseline has improved, erasing the evidence of clinical change. Conversely, recall bias can contribute to a placebo effect. With the exception of 1 dog, the variability in each owner’s visual analogue scale for each variable suggested that owners gave each period careful consideration and were not influenced by a placebo effect. Therefore, we speculate that the overall consistent improvement from the preoperative to the combined postoperative periods indicated long-term treatment efficacy with regard to patient comfort and function.

c. Questionnaire available upon request.

References


Appendix

Lameness grading scale used in a study of 12 dogs treated via distal femoral osteotomy for combined distal femoral varus and medial patellar luxation.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>No lameness detected.</td>
</tr>
<tr>
<td>1</td>
<td>Barely perceptible lameness.</td>
</tr>
<tr>
<td>2</td>
<td>Mild or inconsistently apparent weight-bearing lameness.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate, obviously apparent weight-bearing lameness.</td>
</tr>
<tr>
<td>4</td>
<td>Severe, predominantly weight-bearing lameness.</td>
</tr>
<tr>
<td>5</td>
<td>Severe, predominantly non–weight-bearing lameness.</td>
</tr>
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