Total knee replacement in a dog with a non-union type B3 tibial plateau fracture

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Summary
A six-year-old German Shorthaired Pointer was presented with a 12 month history of left pelvic limb lameness following trauma. Clinical examination revealed marked thickening and reduced range-of-motion of the left stifle and radiographs were suggestive of a non-union type B3 tibial plateau fracture with severe secondary osteoarthritis. Total knee replacement was performed with adjunctive stabilization of the proximal tibial fracture fragment. Clinical follow-up at six and 12 months with quantitative gait analysis revealed significant improvement in limb function.

Case report

A six-year-old, male neutered, German Shorthaired Pointer was presented with a one year history of left pelvic limb lameness. Lameness had manifested acutely after the dog ran into a flower pot. A superficial wound had been present on the cranial aspect of the stifle joint at the time of this injury. The soft tissue injury was explored locally prior to the wound being closed by the referring veterinary surgeon. Radiographs of the left pelvic limb had been obtained at this time and were deemed to be unremarkable. Conservative management of the lameness was recommended, comprising rest as well as the administration of non-steroidal anti-inflammatory medication. This resulted in a transitory improvement in lameness over the following eight month period. However, in the four months prior to referral, lameness in this limb had progressed, becoming recalcitrant to non-steroidal anti-inflammatory medication such that the dog was...
non-weight bearing on this limb when standing (Figure 1) and would only occasionally ‘toe-touch’ the limb to the ground when walking.

Examination of the limb revealed pronounced peri-articular thickening and effusion of the left stifle. Stifle flexion was reduced by 40 degrees (80° left and 40° right) and extension was reduced by 10 degrees (150° left and 160° right). Thigh girth, at the level of the mid-diaphysis of the femur was also reduced by 3 cm in this limb (31 cm and 34 cm right) and signs of pain were evident on forced flexion of the joint. Collateral stability was palpably normal and there was no evidence of cranial or caudal drawer.

Orthogonal radiographs of the left stifle joint were obtained (Figure 2). These revealed severe effusion and moderate to severe new bone formation on the base and apex of the patella, the medial and lateral aspects of the tibial plateau, the femoral condyles and the fabellae. In addition, the craniocaudal projection revealed a subtle discontinuity in the lateral tibial articular surface suggestive of fracture affecting the caudolateral articular margin of the tibial plateau. Arthrocentesis of the left stifle revealed low numbers of nucleated cells (2 cells per 500 x field) that were predominantly large mononuclear cells with basophilic vacuolated cytoplasm. These changes were consistent with chronic osteoarthritis. No organisms were observed.

Due to the chronicity of the fracture, the severity of osteoarthritic change, persistent pain and poor limb function, knee replacement was advocated as the most appropriate treatment modality.

**Surgical technique**

In accordance with a previously published technique, a 30 mm tibial component and 32 mm femoral component were templated from radiographs prior to surgery (13). The dog was positioned in dorsal recumbency and a lateral parapatellar arthroscopy was performed with retroflexion of the patella medially. Due to the poor flexion evident in this limb, the tibial fracture was not readily visible despite resection of the infrapatellar fat pad, cranial and caudal cruciate ligaments, and both menisci. Following placement and alignment of the extramedullary tibial alignment guide and cranial subluxation of the tibia, the tibial plateau was ostectomized using an oscillating saw. Following removal of the tibial plateau en bloc, inspection of the tibial surface revealed a fracture affecting the caudo-lateral aspect of the proximal tibia (Figure 3). The fracture surfaces were markedly sclerotic and smooth, consistent with chronic instability at this site. Following placement of the 32 mm femoral cutting block and osteotomy of the femoral articular surface, suggesting fracture at this site.

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Figure 2  a) Mediolateral and b) craniocaudal radiographic images of the left stifle showing severe effusion and osteophytosis of the apex and base of the patella, the medial and lateral tibial plateau, the femoral condyles, and the sesamoid bones. c) Close-up of (b) revealing subtle discontinuity of the caudo-lateral tibial plateau articular surface, suggesting fracture at this site.

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**Figure 1** Prior to surgery the dog had extremely poor left pelvic limb function and would typically hold the limb off of the ground the majority of the time when standing and walking.
icular surface, the 30 mm tibial trial component was placed on the tibial osteotomy surface and aligned with the tibial long axis via an attached drop rod as previously described (13). A 7 mm diameter drill bit was used to drill a 22 mm deep keel hole through the tibial trial component into the tibial metaphyseal bone bed. The fracture line did not communicate with the keel hole, thus allowing preservation of circumferential metaphyseal cancellous bone. The drill bit was maintained in situ, while two pairs of fragment forceps were placed in a caudolateral to craniomedial orientation to reduce and compress the proximal tibial fracture fragment against the tibial metaphysis. Following reduction, a 2.5 mm drill hole was made from the fibular head and lateral fracture fragment 1 cm distal to the osteotomized tibial surface. The hole was angled approximately 10° caudal to the tibial trial component keel hole with the 7 mm drill bit still in situ, thus protecting the keel hole from damage. A 3.5 mm cortical bone screw and washer were then placed in this hole. An anti-rotational 1.6 mm Kirschner wire was then placed proximal and parallel to this screw, again oriented caudally relative to the keel hole. Following removal of the fragment forceps, the 7 mm drill keel was removed from the tibia. A +5, 30 mm trial tibial component and a 32 mm trial femoral component were placed, and following temporary reduction of the patella, the limb was palpated through its entire range-of-motion to assess for appropriate soft tissue tension. As this was deemed appropriate, a +5 monoblock ultrahigh molecular weight polyethylene tibial component was inserted using bone cement, and a 30 mm cobalt chrome cementless femoral component was placed without any bone cement. The surgical incision used to approach the stifle joint was closed routinely. 

Postoperative radiographs are shown in Figure 4. Assessment of the femoral component revealed good contact with the femoral long axis on the cranio-caudal projection. Orientation of the femoral component post with respect of the femoral long axis on the mediolateral projection revealed the component to be placed in approximately 10 degrees of relative flexion. The patella was normally aligned and reduced on the femoral component. The tibial component was not readily visible, but as referenced by its articulation with the femoral component on the cranio-caudal projection and the outline of bone cement surrounding the keel and distal surface, it appeared of appropriate size and well-aligned axially. Postoperative range-of-motion was identical to preoperative values.

**Postoperative management**

Postoperative analgesia comprised methadone® (0.3 mg/kg IV every 4 hours) for 24 hours followed by buprenorphine® (0.02 mg/kg IV every 6 hours) for 48 hours followed by a seven day course of oral tramadol® (50 mg every 8 hours) for 10 days. Firocoxib® (5 mg/kg orally once daily) was administered postoperatively for six weeks and a 10 day course of cephalaxin® (20 mg/kg orally twice daily) was prescribed. Postoperative rehabilitation comprising ice packing, passive range-of-motion exercises and limb massage was instigated immediately following surgery as per a previously described rehabilitation protocol (13). Hydrotherapy was not utilized as the dog seemed to be scared of water and because it reacted adversely when placed in the pool. Sutures were removed two weeks following surgery and room rest advised for six weeks with short lead walks.

Six weeks following surgery, the dog returned for repeat evaluation. At this time, limb function was improved when compared to preoperatively in that the dog would place its limb on the ground the majority of the time when slowly walked and standing, but still had a tendency to be non-weight bearing on the limb when trotting. Radiographs were performed that revealed no change in implant position (Figure 4). Slight thickening of the patella tendon was observed together with mild new bone formation on the apex of the patella. Range-of-motion of the joint and measurement of thigh girth were unchanged compared to preoperative values. A further six week course of firocoxib was prescribed and incrementally increasing lead exercise was recommended over

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d Optipac™ Refobacin Bone Cement R: Biomet, Warsaw, Indiana, USA

g Tramadol: Bristol Laboratories Ltd, Herts, U.K.
h Previcox: Merial, Duluth, Georgia, U.S.A
i Therios: Alstoe Animal Health Ltd, York, U.K.
the subsequent eight week period. Telephone conversation with the owners at 12 weeks postoperatively revealed limb function to have improved substantially with the dog weight bearing all of the time when walking and trotting.

The dog was re-examined six and 12 months postoperatively. At these time points it was not being treated with any medication, and was allowed unrestricted exercise each day. The dog was observed to be weight bearing 100% of the time. Goniometry of the pelvic limbs revealed no change in range-of-motion of either stifle joint from postoperative values. Thigh girth was increased in the left pelvic limb to 32 cm at six months and 33 cm by 12 months at this stage being identical to that of the contralateral limb. On both occasions, signs of pain were not elicited on palpation of the left stifle joint. The owner declined radiological evaluation of the implants at the six and 12 month re-evaluation appointment.

Gait analysis

Inverse dynamics analysis was performed at six and 12 months postoperatively. Gait analysis was not performed preoperatively or at six weeks postoperatively as the dog was not consistently weight-bearing on the left pelvic limb at a trot. Each pelvic limb was modelled as a linked-segment system of five segments using a generic morphometric description based on total body mass and skin markers on osseous land-

**Figure 4** a) Mediolateral and b) craniocaudal postoperative and c) mediolateral and d) craniocaudal six week postoperative radiographs.

**Figure 5** Total support moment at six and 12 months post-surgery. Solid black line is the right limb, and dashed black line is the left limb.
marks following the procedure outlines by Colborne and colleagues (3). The dog was allowed to find its own comfortable speed, and the handler maintained that speed across all trials. Marker position was recorded in three dimensions by four infrared cameras\(^j\) operating at 200 Hz in parallel with a force platform\(^k\) embedded flush within the runway. Data from trials where the camera-side hind paw landed near the centre of the force platform, and the dog was trotting unencumbered and at constant velocity, were saved to disk. Six ‘good’ trials were saved for each limb. The positional and force data were combined with the morphometric data in a custom program for calculation of limb segment and joint angular displacements, net joint moments, and joint powers using inverse dynamics. Net negative joint moments were caudal (plantar). Total support moment was calculated by summing the individual net joint moments after reversing the stifle moment to make all extensor moments negative. Data were time-normalised to stance duration (101 data points) and averaged across the six trials per limb. Paired t-tests were used to compare velocities of right and left limb trials at six months and at 12 months, and to compare velocities between six and 12 months.

**Results**

There was no significant difference in mean (standard deviation) trotting velocity between the right and left limb trials at six months (Right: 2.52 ms\(^{-1}\) [0.22]; Left: 2.40 ms\(^{-1}\) [0.15]; \(p = 0.366\)) or at 12 months (Right: 2.20 ms\(^{-1}\) [0.17]; Left: 2.12 ms\(^{-1}\) [0.03]; \(p = 0.706\)). However, the dog trotted significantly more slowly at 12 months compared to six months (6 months: 2.46 ms\(^{-1}\) [0.19]; 12 months: 2.16 ms\(^{-1}\) [0.13]; \(p < 0.001\)). Notwithstanding the reduction in

\(^j\) ProReflex: Qualisys Medical AB, Gothenborg, Sweden

\(^k\) Model 9287: Kistler Instrumente AG, Winterthur, Switzerland

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trotting velocity at 12 months, the mean peak vertical forces were similar although there was a flattening of the vertical force profile for the left limb at six months. Mean peak vertical ground reaction forces were 117 Nkg⁻¹ and 115 Nkg⁻¹ for the left limb at six and 12 months respectively, and 147 Nkg⁻¹ for the right limb at both measurement sessions. Peak braking and propulsive forces were slightly reduced in both limbs at the 12 month measurement, reflecting the reduction in trotting velocity. The mean peak braking forces in the left limb were −13 Nkg⁻¹ at six months and −9 Nkg⁻¹ at 12 months, and in the right limb were −29 Nkg⁻¹ and −17 Nkg⁻¹ respectively. The mean peak propulsive forces in the left limb were 20 Nkg⁻¹ at six months and 16 Nkg⁻¹ at 12 months, and in the right limb were 34 Nkg⁻¹ and 25 Nkg⁻¹ respectively. The slower trotting velocity and smaller ground reaction forces at 12 months affected the total support moments, which were likewise smaller at 12 months in both limbs. Figure 5 shows that total support moment for the left limb was −1.86 Nmkg⁻¹ and −1.43 Nmkg⁻¹ respectively.

The stifle joint angle curves (Figure 6) indicate that the left stifle joint underwent a smaller angular excursion than the right at both measurement times. At 12 months, the left stifle joint was more extended in stance by approximately 10 degrees compared to its position at six months, and the right stifle was likewise more extended by about five degrees. The moment profiles conformed to the normal shape and amplitudes at six months, but at 12 months the right stifle had a reduced flexor moment in early stance, and an earlier and larger extensor moment in mid- to late stance, while the left stifle moment was reduced throughout. The power from the left stifle flexors was small in early stance at both measurement sessions, and then oscillated around zero for the remainder of the stance, which was a consequence of the small angular excursion of the stifle joint in mid- to late stance. At six months, the right stifle joint demonstrated a normal flexor burst in early stance as the stifle flexors flexed the stifle through a concentric contraction. The stifle then extended in late stance with a concentric burst from the stifle extensors. At 12 months, the flexor burst in early stance was reduced, concomitant with the smaller flexor moment and smaller trotting velocity.

In contrast, left hip concentric power was large (Figure 7) in early stance at six months, reflecting increased reliance on the hip extensors for support and propulsion on the left side. Concentric hip power was reduced on both sides at 12 months, perhaps contributing to the smaller velocity observed at this measurement time. Tarsal power was low on the left side, but unaffected by time. The smaller ground reaction forces borne by the left limb contributed to the smaller joint moments, which in turn contributed to the smaller powers. Typically, the stifle replacement limb was held more vertically through stance, and this reduced the moment arms around which the ground reaction forces acted, which combined with the smaller forces to reduce the joint moments. The very small braking forces in early stance suggest this is the case, and the combination of the small left stifle joint angular excursion, the very small tarsal power and

Figure 7  Hip and tarsal powers at six and 12 months post-surgery. The solid black line is the right limb, and the dashed black line is the left limb.
the flat total support moment profile suggests that the limb joints were relatively stiff through stance as the limb bore weight.

Discussion

This case report describes the successful management of end stage osteoarthritis of the stifle joint secondary to chronic non-union caudo-lateral tibial articular fracture. The stifle was managed by fracture stabilisation and total knee replacement. Stifle arthroplasty has previously been reported in a small case series of dogs with end stage osteoarthritis secondary to orthopaedic developmental and degenerative disease as well as in single case reports with adjunctive distal femoral condylar bone loss and trauma associated osteoarthritis secondary to distal femoral fracture (13–15). In humans, total knee replacement in patients with a prior history of knee fracture have reduced success rates (47%) when compared to patients that have routine primary total knee arthroplasty (88–95%), both in terms of propensity for complications, as well as ultimate function achieved (16–18). This is also mirrored in the limited number of published case series where arthroplasty performed in dogs as a salvage procedure secondary to trauma achieved reduced function in terms of peak vertical forces (65%) compared to those patients undergoing elective arthroplasty without trauma associated osteoarthritis (13, 14). This is mirrored in the case described herein where a mean peak vertical force of only 60% was recorded on the compensating side. Factors which may deleteriously influence outcome in humans undergoing knee arthroplasty with a prior history of tibial plateau fracture include: young age at the time of surgery, alteration of the weight bearing axis, soft tissue envelope compromise, difficulty with surgical exposure, ligamentous balancing, and poor arc of knee motion (19). Surgical exposure was challenging in our case due to the poor stifle flexion, especially with regards to inspecting the caudal aspect of the tibial plateau, although this did not deleteriously impact on placement of the femoral or tibial components. A significant reduction in preoperative stifle range-of-motion was evident in this limb, especially in flexion compared to the contralateral side and compared to the non-fracture associated stifle arthroplasties previously reported and this may have contributed to the reduction in the final peak vertical force achieved in this case (13).

Conflict of interest

None declared.

References

10. Llinas A, McKellop HA, Marchall GJ, et al. Healing of femoral condylar bone loss and trauma associated osteoarthritis (13, 14). This is mirrored in the limited number of published case series where arthroplasty performed in dogs as a salvage procedure secondary to trauma achieved reduced function in terms of peak vertical forces (65%) compared to those patients undergoing elective arthroplasty without trauma associated osteoarthritis (13, 14). This is mirrored in the case described herein where a mean peak vertical force of only 60% was recorded on the compensating side. Factors which may deleteriously influence outcome in humans undergoing knee arthroplasty with a prior history of tibial plateau fracture include: young age at the time of surgery, alteration of the weight bearing axis, soft tissue envelope compromise, difficulty with surgical exposure, ligamentous balancing, and poor arc of knee motion (19). Surgical exposure was challenging in our case due to the poor stifle flexion, especially with regards to inspecting the caudal aspect of the tibial plateau, although this did not deleteriously impact on placement of the femoral or tibial components. A significant reduction in preoperative stifle range-of-motion was evident in this limb, especially in flexion compared to the contralateral side and compared to the non-fracture associated stifle arthroplasties previously reported and this may have contributed to the reduction in the final peak vertical force achieved in this case (13).

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