Rotating dome trochleoplasty: An experimental technique for correction of patellar luxation using a feline model

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Introduction

Patellar luxation is one of the most common orthopaedic diseases of the pelvic limbs in dogs (1) and has also been reported in cats (2–4). Both small and large breeds of dogs can be affected, with the majority of luxations occurring medially (1) and a reported incidence of 60–90% (5). The disease can be traumatic, but it is most often developmental (1) and may result in the development of pain, lameness and osteoarthritis (OA) (5). Surgical correction has become the standard treatment in dogs exhibiting clinical signs associated with patellar luxation. In general, surgical intervention includes: tibial crest transposition, joint capsule imbrication, desmotomy and deepening of the femoral trochlea (5). Reported success rates for surgically corrected patellar luxations range from 79% (9) to over 90% (13). There is a 50% reported recurrence rate of non-clinical grade 1 patellar luxation after surgical correction (9).

Trochleoplasty is used to correct femora with inadequate trochlear depth associated with patellar luxation (6). Reported trochleoplasty methods in dogs include: excisional trochleoplasty (7, 8), trochlear chondroplasty (9), trochlear wedge recession (TWR) (10, 11), and, more recently, trochlear block recession (TBR) (6). Any exposed cancellous bone is eventually covered by fibrocartilage during normal healing (12). Fibrocartilage is weaker in comparison to hyaline articular cartilage, which may predispose animals to osteoarthritis (12); therefore, a key goal of trochleoplasty techniques is to preserve normal hyaline articular cartilage (5). Currently, TBR and TWR are the only two reported trochleoplasty techniques that can recess the femoral trochlea while preserving most of the articular cartilage in adult dogs (5). It has been shown in vitro that a TBR procedure preserved more hyaline articular cartilage, recessed a larger percentage of the trochlear surface area, and resulted in greater resistance to patellar luxation with the stifle in an extended position when compared to TWR (5).

It was hypothesized that a shallow trochlear groove could be corrected by rotating a portion of the trochlea to increase the height of the medial trochlear ridge (in the case of a medially luxating patella), while preserving more hyaline articular cartilage than a TBR. The aim of this study was to create a trochleoplasty technique that would prevent patellar luxation and preserve more hyaline articular cartilage, which may minimize the progression of osteoarthritis in clinical cases. The objectives of this study were to describe a novel rotating dome trochleoplasty (RDT) and compare it to a TBR.

Materials and methods

Patellar luxation model

Twenty-eight pelvic limbs from fourteen feline cadavers obtained from a local humane society were used for this study. All cats were euthanized for reasons unrelated to hind-limb pathology. The cats’ weights ranged from 2.1 kg to 4.2 kg (median 2.8 kg). In total, four skeletally immature pelvic limbs were used; there were four limbs in each group. The cats were stored at –20°C and thawed at room temperature for 18 hours im-

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mediately prior to use. The pelvic limbs were left attached to the body for this study. An approach to the stifle joint through a lateral incision (15) was performed. In an attempt to mimic a clinical situation, a grade two medial patellar luxation was created in all pelvic limbs. A high speed burr\(^a\) was used to remove hyaline cartilage and subchondral bone from the medial trochlear ridge of the first femur until a grade two patellar luxation was achieved. To replicate the shape of the first trochlea, a metal mould was made at three separate points (proximal third, distal third and middle) along the trochlea of the first stifle, which provided a template for the rest of the stifles (Fig. 1). The trochlear width and depth of the stifles were measured with electronic calipers\(^b\) to ensure precision of burring. Each cadaver had TBR performed on one limb and RDT on the other. The procedures were randomized (coin-toss) with respect to order and side such that seven left and seven right limbs had TBR performed while the contralateral limbs from each pair had RDT performed.

**Trochlear block recession**

A trochlear block recession was performed as previously described (5). Briefly, with the cats in dorsal recumbency, the patella was luxated medially and a fine handsaw\(^c\) was used to create parallel, longitudinal trochlear cuts at the apex of the medial and lateral trochlear ridges. A 4 mm fine osteotome and a mallet were used for the basilar cut. The osteochondral segment was temporarily removed and a 1 mm section of bone as measured with electronic calipers was then removed from the base of the trochlea with an osteotome to deepen the groove. The osteochondral segment was replaced and the patella was anatomically reduced (Fig. 2A). The joint capsule incision was closed in a simple continuous pattern using 3–0 polydioxanone\(^d\) suture and the skin apposed in a Ford interlocking pattern using 4–0 polybutester\(^d\) suture.

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\(a\) Surgairetome, 3M / Linvatec Corp., Largo, FL, USA.
\(b\) PDS II, Ethicon, Somerville, NJ, USA.
\(c\) Securos, Charlton, MA, USA.
\(d\) Novofil, Davis & Geck, Wayne, NJ, USA.
Rotating dome trochleoplasty

A 14 mm gouge was modified to create a 12 mm diameter hemi-circular osteotome (Fig. 3). With the cats positioned in dorsal recumbency, the modified gouge and a mallet were used to remove a domed section of bone from the femoral trochlear groove. The osteotomy was started at the distal aspect of the trochlea, centered through the apex of the lateral trochlear ridge and extended 1–2 mm medial to the apex of the medial trochlear ridge as measured with calipers. The osteochondral segment was rotated 1 mm medially (measured with calipers) to increase the height of the medial trochlear ridge (Fig. 2B). The section of bone was stabilized in the same manner as in TBR; by friction and compression of the overlying patella (5) when the arthroscopy was closed. The arthroscopies were closed in the same manner and using the same suture material as the TBR.

Computed tomography and statistical analysis

Computed tomographic evaluation was performed on the limbs after completion of the TBR and RDT procedures. Each stifle was manually cycled 30 times through a full range of motion prior to placing the cats in a plastic trough for scanning. The limbs were scanned in both the extended (140°) and flexed (110°) positions as measured with a goniometer centered proximally over the greater trochanter, the middle of the stifle joint and distally over the lateral malleolus of the fibula. The computed tomography (CT) scan thickness was set at 0.625 mm which yielded a mean of 20 (range 18 to 24) axial sections per patella. Both stifles of each cadaver were scanned simultaneously. The CT images were digitized and measurements were made with an image-analysis software program.

The patellar volume (PV) of each stifle was estimated by summing the area of the patella in each CT section and multiplying it by the scan thickness (Fig. 4A). The patellar volume covered by the trochlear ridges (PVT) was similarly obtained by calculating the volume of the patella located below a line through the medial and lateral trochlear ridges (Fig. 4B). The total trochlear surface area preserved (TSA) was calculated by multiplying the CT axial scan width by the sum of the lengths of the trochlear groove in each CT axial image where the patella was visible (Fig. 4C). The trochlear-to-patellar surface area (TPSA) was calculated in a similar manner as TSA. Instead of measuring the entire surface area of the trochlea, only the area in direct contact with the patella was recorded (Fig. 4D). For the medial trochlear ridge height (MTRH), an axial CT image, which contained both the medial and lateral femoral epicondyles, was selected. Next, the distance was calculated between the widest aspect of the medial-to-lateral femoral epicondyle and the medial trochlear ridge (Fig. 4E). The trochlear width (TW) of each stifle was calculated by averaging the distance from the apex of the medial to lateral femoral condyles in each section containing a portion of the patella (Fig. 4F). The trochlear depth (TD) was defined as the average height from the deepest point in the trochlear sulcus to the apex of the medial trochlear ridge in each stifle (Fig. 4G). The patellar tilt angle (PTA) was assessed by the angle created at the intersection of a line through the widest section of the patella and a line drawn through the medial and lateral femoral epicondyles (Fig. 4H). Statistical analysis was completed using a Wilcoxon signed-rank test. A statistical software package was used to process the data. Findings were considered statistically significant if p-value was <0.05.

GE Discovery LS PET/CT Scan, Piscataway, NJ, USA.

Statistix 8 Software Package, Tallahassee, FL, USA.

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Fig. 4 a) CT images illustrating measurements for; patella volume, b) patellar volume covered by trochlear ridges, c) total trochlear surface area, d) trochlear-to-patellar surface area, e) medial trochlear ridge height, f) trochlear width, g) trochlear depth, h) patellar tilt angle.
Results

Fracture of the osteochondral segments to the level of, but not through the articular cartilage, occurred in one of the RDT cases and three of the TBR cases. All of these cases were included in the statistical analysis.

In comparison to the TBR group, the RDT group demonstrated a significant increase in trochlear articular surface area preserved in both flexion (10% increase, \(P=0.008\)) and extension (17% increase, \(P<0.001\)). The medial trochlear ridge height of the RDT group was significantly higher in flexion (10% higher, \(P=0.001\)) and in extension (15% higher, \(P<0.001\)) when compared to the TBR group. Finally, the RDT group had a significantly greater trochlear width (16% deeper, \(P=0.035\)) and trochlear depth (43% deeper, \(P=0.03\)) than the TBR group in extension (Table 1).

Table 1 CT Measurements of the RDT and TBR groups.

<table>
<thead>
<tr>
<th></th>
<th>Flexion Median difference RDT-TBR (% difference)</th>
<th>P-value</th>
<th>Extension Median difference RDT-TBR (% difference)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV (mm(^3))</td>
<td>0.25 (0.001%)</td>
<td>&gt;0.95</td>
<td>0.69 (0.004%)</td>
<td>0.30</td>
</tr>
<tr>
<td>PVC (mm(^3))</td>
<td>3.8 (12%)</td>
<td>0.30</td>
<td>1.5 (15%)</td>
<td>&gt;0.20</td>
</tr>
<tr>
<td>TSA (mm(^2))</td>
<td>6.3 (10%)</td>
<td>0.008</td>
<td>10.3 (17%)</td>
<td>0.0002</td>
</tr>
<tr>
<td>ANTR (mm)</td>
<td>0.6 (10%)</td>
<td>0.001</td>
<td>0.92 (15%)</td>
<td>0.0006</td>
</tr>
<tr>
<td>TPAS (mm(^2))</td>
<td>0.15 (&lt;1%)</td>
<td>0.59</td>
<td>3.5 (7%)</td>
<td>0.09</td>
</tr>
<tr>
<td>TW (mm)</td>
<td>0.55 (8%)</td>
<td>0.10</td>
<td>0.43 (6%)</td>
<td>&lt;0.035</td>
</tr>
<tr>
<td>TD (mm)</td>
<td>0.22 (16%)</td>
<td>&gt;0.15</td>
<td>0.51 (41%)</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>PTA (degrees)</td>
<td>0.5(^\circ) (8%)</td>
<td>&gt;0.8</td>
<td>0</td>
<td>&gt;0.54</td>
</tr>
</tbody>
</table>

PV = patellar volume; PVC = patellar volume covered by trochlear ridges; TSA = trochlear articular surface area preserved; ANTR = medial trochlear ridge height; TPAS = trochlear-patellar actual articular surface area; TW = trochlear width; TD = trochlear depth; PTA = patellar tilt angle.

Discussion

Feline stifles were predominantly used for this study due to their availability and the fact that patellar luxation has been reported in cats (2–4). Furthermore, the stifles were anatomically close in size between subjects, making the creation of an accurate patellar luxation model possible. Since patellar luxation is more commonly seen as a clinical problem in dogs, subsequent studies should be conducted in dogs in order to determine the applicability of RDT in that species.

Fracture of the osteochondral segments occurred in the second RDT performed and in the first, third and fourth TBR performed. Two fractures in the TBR group occurred along the distal femoral growth plate. The other possible cause of fragment fracture was due to a learning curve in performing the procedures. The tapered end of the osteotome caused it to exit the bone more distal than was intended. Redirecting the osteotome created tension on the osteochondral segment which most likely resulted in the fractures. This complication was minimized by starting the osteotomy with the osteotome positioned at a right angle to the bone followed by gradual angulation of the osteotome to exit the femur at the proximal aspect of the trochlear groove. These stifles were included in the study due to the fact that the articular surface and geometry of the partially fractured fragments were undisturbed, and fracture of the osteochondral segment is a reported complication of trochleoplasty techniques (5).

There was not a significant difference in measured patellar volume of the stifles within each group when compared in flexion and extension. This indicated that our method of measuring parameters using the software program was precise; however, the overall accuracy was limited due to the inability to visualize hyaline cartilage on CT images.

The limbs were scanned in 140 degrees of extension and 110 degrees of flexion. These angles were chosen based on a previous study (1) which was the range of flexion and extension in a dog during a walk. The stifles were manually flexed and extended through a range motion prior to CT scans to determine if there was a tendency for the osteochondral fragments to migrate. Migration was not observed in either of the study groups although this was a subjective assessment. Biomechanical testing in a materials testing machine would be required to objectively evaluate osteochondral segment stability and aid in assessing resistance to luxation during internal and external rotation of the tibia. A rotation of 1 mm was measured at the medial trochlea to match the depth of the block recession in the TBR group for direct comparison of the two procedures. In clinical cases the amount of rotation necessary to prevent patellar luxation will likely vary among individuals.

In most cases, trochleoplasty techniques should be combined with other methods of stabilization including, but not limited to, corrective femoral or tibial osteotomy, tibial crest transposition and joint capsule and fascial imbrication. This model did not account for the various tibial and femoral deformities commonly seen in dogs and cats with patellar luxation, as the cats used in this study did not have any obvious skeletal abnormalities.

It was noticed subjectively that there seemed to be an excessive angle of the patella (patellar tilt) relative to the medial and lateral femoral epicondyles in the axial images of the RDT group; however, a significant difference in patellar tilt was not found between the two procedures. Patellar tilt may cause abnormal pressure on articular cartilage of the patella and trochlea which results in chondromalacia. Since previous studies in dogs and cats have not reported the normal angle of the patella relative to the medi-
al and lateral femoral epicondyles, it may have been advisable to measure the preoperative patella tilt angle to compare the two procedures to normal stifles.

Overall, there was an increase in every measured parameter in the RDT group when compared to the TBR group. There was also a trend towards an increase in TW in flexion and TPAS in extension. Potential advantages of RDT include: greater preservation of hyaline cartilage, which may minimize the development of DJD and result in a faster return to limb function (5), and the increased height of the medial trochlear ridge, which may aid in resisting patellar luxation. Technically, the RDT procedure had a small learning curve and was fairly easy to perform, requiring only a single cut to complete the trochleoplasty, which may decrease surgical time. The RDT is a versatile technique that could be customized to meet specific needs of individual stifle conformations as the medial or lateral trochlear ridge height could be augmented by rotating the dome as required. The technique could possibly be modified by replacing the osteochondral segment proximally in cases of patella alta.

**Conclusion**

The rotating dome trochleoplasty proved to be a promising technique that was equal or superior to a trochlear block recession technique with regard to the measured parameters of this cadaver study. The clinical usefulness of this procedure in cats and dogs is currently unknown, however, the results of this study warrant further evaluation of this technique which may eventually include clinical trials. Prior to clinical trials, biomechanical studies should be performed which examine the resistance to medial patellar luxation and the stability of the transposed trochea in canine cadavers.

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