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TECHNICAL NOTE

An optimized medial parapatellar approach to the goat medial femoral condyle

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Abstract

Goats or sheep are the preferred animal model for the preclinical evaluation of cartilage repair techniques due to the similarity of the goat stifle joint to the human knee. The medial femoral condyle of the stifle joint is the preferred site for the assessment of articular cartilage repair, as this is the primary location for this type of lesion in the human knee. Proper surgical exposure of the medial femoral condyle is paramount to obtain reproducible results without surgical error. When applying the standard human medial arthrotomy technique on the goat stifle joint, there are some key aspects to consider in order to prevent destabilization of the extensor apparatus and subsequent postoperative patellar dislocations with associated animal discomfort. This paper describes a modified surgical technique to approach the medial femoral condyle of the caprine stifle joint. The modified technique led to satisfactory exposure without postoperative incidence of patellar luxations and no long-term adverse effects on the joint.

KEYWORDS

approach, arthrotomy, cartilage, condyle, goats

1 | INTRODUCTION

Regulatory agencies in translational medicine, such as the Food and Drug Administration and notified bodies, advocate the use of large animals for preclinical evaluation of innovative therapies or medical devices in the field of cartilage repair.[1] The anatomy of goat and sheep stifle joints is similar to that of the human knee,[2] and the stifle joint is thus often used as a preclinical animal model for the evaluation of cartilage repair techniques.[3] In comparison to that of sheep, the goat stifle joint is more similar to the human knee with regard to cartilage thickness and subchondral bone architecture.[4,5] Therefore, the caprine model is more commonly applied in cartilage repair research.[6-9]

The medial compartment of the knee experiences 60%-80% of the weight-bearing load during normal bipedal ambulation in humans, and, consequently, is most affected by cartilage pathologies.[10-14]

Exposure of the medial compartment of the caprine stifle joint is commonly achieved using a medial parapatellar approach combined with intraoperative patellar luxation similar to knee arthrotomies in humans.[15] However, applying this approach can result in significant postoperative morbidity due to patellar luxation. In the caprine and ovine stifle joint, the patella is engaged in the trochlea during

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flexion, while the patellar stability relies on the oblique medial vastus tendon and the medial patellar retinaculum (MPR) in extension. Intraoperative patellar luxation after a medial parapatellar approach requires release of these ligaments, possibly resulting in patellar instability during extension and subsequently increasing the risk of postoperative patellar luxation to as high as 25%. A previously published paper by Orth et al describes a low morbidity surgical approach to the femoral trochlea of sheep.[16] Using this technique, the trochlea is approached using a mini-arthrotomy without intraoperative patellar luxation.

In the context of focal knee resurfacing implant (FKRI) preclinical evaluation, implant positioning and alignment is crucial.[17] Applying the trochlear approach as described by Orth et al to the goat medial femoral condyle did not result in sufficient surgical exposure to allow for guidance tool usage, thus necessitating modification of the technique. This paper describes the most important modifications and their considerations based on the authors' experience during the adoption and optimization of the low morbidity approach to the goat medial femoral condyle over the course of 3 years, in which three series of animal trials were conducted in the context of preclinical evaluation of a FKRI.

2 | METHODS

2.1 | Study design

Three series of animal trials were conducted in the context of the preclinical evaluation of a focal knee resurfacing implant (FKRI). The consecutive studies consisted of a 3-, 6- and 12-month follow-up. All animals in the 3-month follow-up group underwent implant placement. In the 6- and 12-month follow-up groups, 8 out of 32 knees underwent sham surgery without the implantation of an implant (Table 1). The protocol was approved by the Dutch Central Authority for Animal Experimentation and the Committee on the Ethics of Animal Experiments of the University of Maastricht (AVD107002016514).

During each trial, exposure of the medial femoral condyle was performed bilaterally in 16 skeletally mature female Dutch milk goats aged 2.09 ± 0.24 years, resulting in a total of 96 approaches to the stifle joint. The surgical technique is described in more detail below. Since MPR release potentially leads to patellar instability, the morbidity of the approach was assessed through the incidence of patellar luxations during a follow-up of 3, 6 and 12 months. The animals were observed daily. In case any gait abnormalities were observed, physical examination followed in order to assess range of motion, patellar location and alignment to determine the presence of a patella luxation. X-rays of sham-operated knees were obtained and evaluated for signs of osteoarthritis as defined by Kellgren and Lawrence[18] at baseline and after final follow-up of 6 and 12 months. Sham-operated condyles were macroscopically assessed for any cartilage damage based on the recommendations by the OARSI histopathology initiative.[19]

2.2 | Surgical technique

The skin incision is made from the base of the patella to the tip of the tuberositas tibiae (Figure 1A). The subcutaneous tissue is then opened in layers with a diathermic knife. (Figure 1B). The pearl-white retinacula continuations should then be easily recognized and are opened using diathermy (Figure 1C). The tight joint capsule is located right underneath the retinaculum and should be opened with great care to avoid damage to the intra-articular tissues. As soon as Hoffa's fat pad (HFP) is visible, a surgical spreader is placed underneath the joint capsule exposing the intra-articular structures (Figure 1D). Partial hoffectomy allows for exposure of the medial femoral condyle (Figure 1E). The most distal part of HFP is kept intact to avoid invoking damage to the medial meniscus. (Figure 2A). After partial hoffectomy, the retinaculum incision is extended proximally until the medial head of the quadriceps muscle is reached. The MPR can now easily be identified just above the apex of the patella. Another modification is cutting of the MPR (Figure 2A). Scissors are used to cut the MPR proximally (Figure 1F). Care should be taken to only cut the MPR and not damage the insertion of the oblique medial vastus muscle potentially leading to undesired further destabilization of the patella. By manual flexion/extension of the knee combined with lower limb endo-/exorotation, the medial condyle, the trochlear side of the lateral condyle, the anterior and posterior cruciate ligaments and anterior third of the menisci should now easily be identified. The medial femoral condyle can be exposed with the knee in full flexion.

TABLE 1 Overview of the study setup and results. During three consecutive animal trials of 3-, 6- and 12-mo follow-ups, a total of 96 goat stifle joints were approached using the modified surgical approach. No patellar luxations were observed during the follow-up. During the 6- and 12-mo follow-ups, 8 knees underwent sham surgery during which the surgical approach was executed without any additional intervention. Before surgery and after final follow-up, X-rays from sham operated knees were obtained and assessed for radiological signs of osteoarthritis (OA) by evaluating joint space narrowing, osteophyte formation and sclerosis. Sham operated condyles were macroscopically evaluated for any signs of cartilage damage by assessing smoothness and integrity

Follow-up	Operated Knees (n)	Luxations (n)	Sham operated knees (n)	Sham operated knees (n = 8) with radiological signs of OA (n)	Sham operated knees (n = 8) with macroscopic cartilage damage (n)
3 mo	32	0	0	–	–
6 mo	32	0	8	0	0
12 mo	32	0	8	0	0

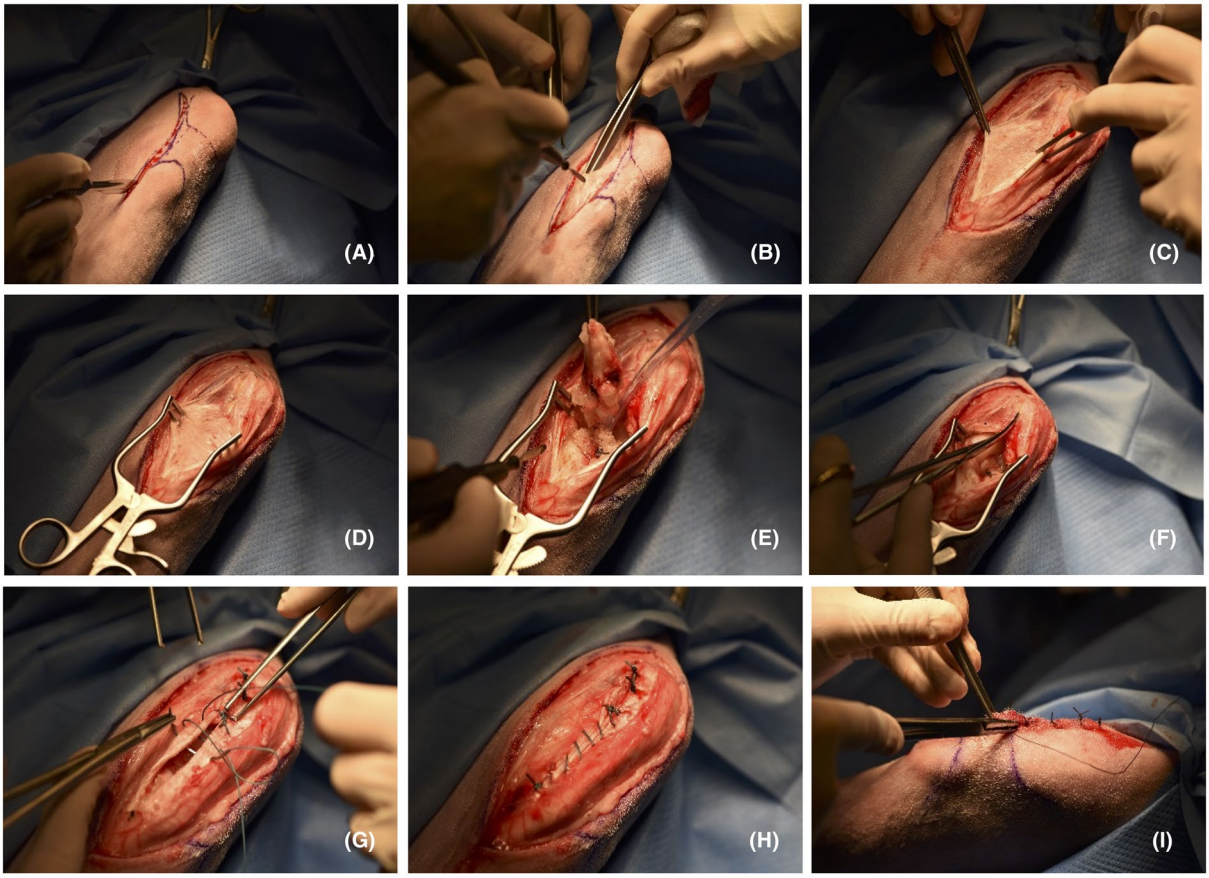


FIGURE 1 Surgical approach and closing of the caprine stifle Joint. A, Skin incision using No. 20 scalpel; B, opening subcutaneous tissue in layers assisted by sliding a pair of tweezers underneath the subcutaneous tissue; C, opening of the retinacula and joint capsules; D, surgical spreader put in place to enhance exposure. Note the appearance of Hoffa's fat pad; E, thorough partial hoffectomy to visualize the medial femoral condyle; F, cutting of the medial patellar retinaculum using surgical scissors; G, two single nonresorbable sutures are placed to suture the medial patellar retinaculum, after which (H) the distal third of the retinaculum and joint capsule are closed using sutures in a continuous fashion; I, the skin is closed using subcutaneous resorbable Vicryl sutures (not shown), additional single sutures are placed to prevent opening of the wound due to biting

After intervention, the MPR is sutured to ensure stabilisation of the patella (Figure 2B). Two separate non-resorbable sutures were used to close the proximal capsule and retinaculum including the MPR (Figure 1G). The distal part of the capsula, including the patellar tendon, is then closed using a continuous suture (Figure 1H). Absorbable sutures are used in a continuous fashion to close the subcutaneous layers. To prevent wound opening by biting, the skin is additionally closed using separate non-resorbable sutures (Figure 1I).

3 | RESULTS

The surgical procedure provided satisfactory exposure of the medial femoral condyle in all 96 stifle joints. The animals recovered quickly and were fully mobile within 2 hours of surgery. During follow-up, no patellar luxations or other complications occurred. After the 6- and 12-month follow-ups, condylar cartilage of sham-operated knees appeared macroscopically intact and smooth. No radiological signs of osteoarthritis were observed (Figure 3; Table 1).

4 | DISCUSSION

This paper describes a low morbidity surgical approach to the medial femoral condyle and the anterior horn of the medial meniscus of the caprine stifle joint. The trochlear approach by Orth et al was extended to adequately expose the medial femoral condyle of goats by performing a partial hoffectomy and by cutting the MPR. The MPR was meticulously sutured using two single non-resorbable sutures, restoring the crucial patellar stability sacrificed during extension of the approach.

Resorbable sutures must be used with caution as they may result in instability due to the lack of long-duration fixation to allow for adequate tissue healing, as described by Orth et al.[16] We used absorbable sutures to suture the MPR during a previous pilot study as we were concerned about the potential adverse effects of long-term intra-articular sutures.[20] The animals were then closely monitored with the risks of delayed post-operative patellar instability in mind, The occurrence of patella luxations in three out of 20 animals necessitated the implementation of non-resorbable sutures in the current study, reducing the patellar luxation rate

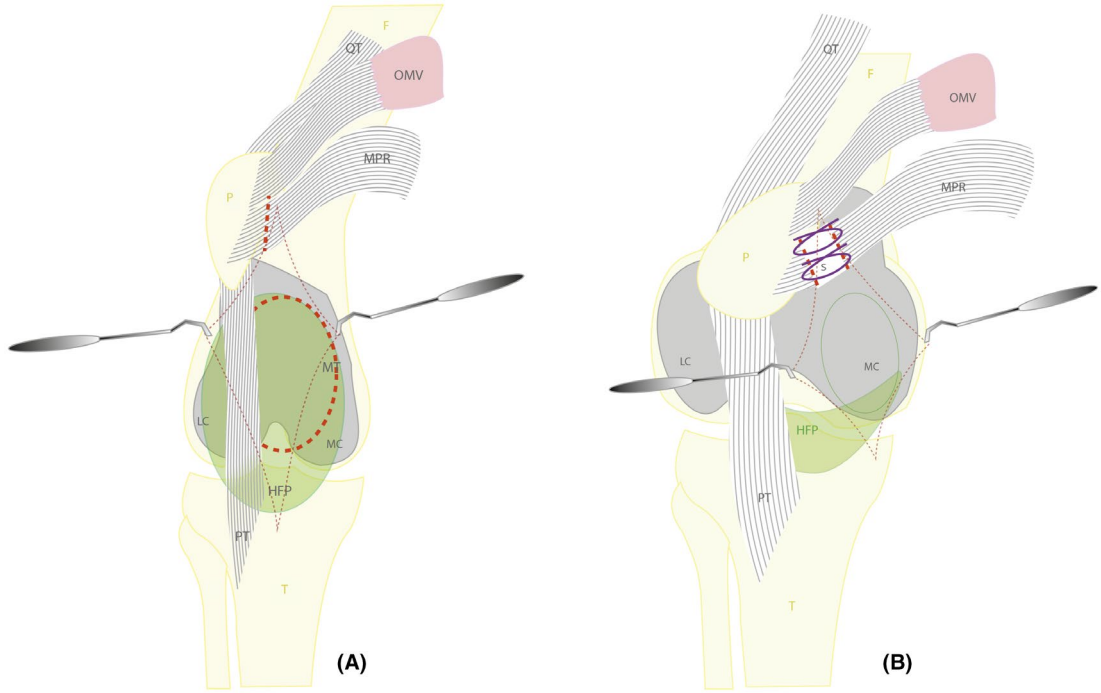
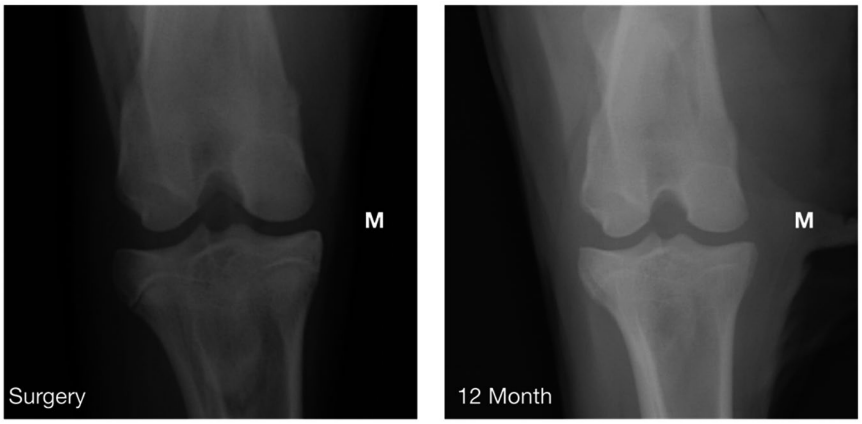


FIGURE 2 Schematic illustration of the relevant anatomy of the goat stifle joint and the low morbidity surgical approach of the medial femoral condyle in goats.A, Shown is the anterior aspect of the opened caprine stifle joint exposing Hoffa's fat pad (HFP) in green. The skin incision is illustrated by the thin dashed red line. To improve visibility, a partial hoffectomy is performed as illustrated by the dashed oval red line. By cutting the medial patellar retinaculum (MPR) as illustrated by the red dashed line, sufficient tension is released to access the medial femoral condyle during full flexion of the stifle joint. B, The joint is depicted after the partial hoffectomy and cutting of the MPR, after which the medial femoral condyle is exposed during full flexion of the stifle joint. After the intervention subject to evaluation has been completed, the MPR is reattached with two single non-absorbable sutures (purple curved lines). F, femur; LC, lateral femoral condyle; MC, medial femoral condyle; MT, medial trochlear facet; OMV, oblique medial vastus muscle; P, patella; PT, patellar tendon PL, patellar ligament; QT, quadriceps tendon; S, sutures; T, tibia

FIGURE 3 Example of an X-ray of a sham knee at baseline and after a 12-month follow-up. In the sham operated knees (n = 8), the surgical procedure was executed without the placement of a focal knee resurfacing implant (FKRI). X-rays were evaluated in order to evaluate any adverse effects of the surgical procedure. "M" denotes the medial side of the knee, which was opened



to zero. No adverse effects of the intra-articular non-resorbable sutures were observed. Therefore, we emphasize the importance of using non-resorbable sutures for joint stabilizing structures as the MPR.

Satisfactory exposure of the medial femoral condyle and anterior horn of the medial meniscus was achieved by applying our modified surgical approach, allowing for accurate FKRI placement. Suturing the MPR with two single non-resorbable sutures provided long-term patellar stability. No adverse effects on the joint were observed, resulting in a low morbidity animal model for evaluating FKRIs and other cartilage repair techniques in a weight-bearing site. This technique could potentially aid in the refinement of animal research in the future by reducing animal discomfort and limiting the interference of surgical complications on study outcomes.[21]

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CONFLICT OF INTEREST

The authors declare they have neither relevant material nor financial interests that relate to the research described in this paper.

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