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Revision surgery with Ridgestop and 3D-printed guides for grade IV canine medial patellar luxation

CHAEWON SUNG[1†], INSUNG JO[2†] and MU-YOUNG KIM[1*]

[1] Department of Veterinary Surgery, College of Veterinary Medicine, Konkuk University, Seoul, Republic of Korea

[2] Inbang Animal Medical Center, Anyang, Republic of Korea

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CASE REPORT

ABSTRACT

A 4-year-old, 3.9 kg spayed female bichon frise presented with persistent lameness following primary medial patellar luxation (MPL) surgery, including tibial tuberosity transposition, trochleoplasty and lateral imbrication. The physical examination indicated a grade IV MPL. Preoperative CT-based 3D reconstructions revealed varus deformity of the distal femur, valgus deformity of the proximal tibia, internal rotation of the tibial tuberosity and bilateral moderate degenerative changes of the coxofemoral joints, with concurrent grade IV medial patellar luxation. The patient underwent revision surgery with distal femoral osteotomy (DFO), proximal tibial osteotomy (PTO) and Ridgestop placement to augment the medial trochlear ridge. To ensure precise intraoperative alignment, preoperative planning utilised virtual 3D planning and 3D printing to fabricate customised osteotomy surgical guides for both DFO and PTO. Postoperative follow-up revealed no further luxation, with stable weight-bearing ambulation. Radiographic analysis confirmed proper limb alignment and Ridgestop implant placement. Ridgestop could offer an effective treatment option for dogs with recurrent patellar luxation when combined with corrective osteotomy.

KEYWORDS

medial patellar luxation, revision surgery, 3D printing, corrective osteotomy, Ridgestop

INTRODUCTION

Medial patellar luxation (MPL) is one of the most prevalent orthopaedic disorders that precipitate hindlimb lameness in canines (Hayes et al., 1994). It has been proposed that coxa vara and a reduced anteversion angle contribute to the development of MPL by causing the quadriceps femoris muscle to shift medially. This displacement leads to skeletal deformities such as distal femoral varus, femoral torsion, a shallow trochlear groove, medial displacement of the tibial tuberosity and internal rotation of the tibia (Soparat et al., 2012; Wangdee et al., 2013).

Surgical intervention aims to restore normal limb function by realigning the extensor mechanism of the stifle joint, employing a comprehensive approach that typically includes deepening of the trochlear groove, lateral imbrication, medial release and lateral transposition of the tibial crest. In grade III-IV MPL, internal rotation of the tibial tuberosity, a shallow or absent trochlear ridge and femoral varus or angular deformities may be present. In severe cases, corrective osteotomy of the femur and the tibia is recommended to address torsional and angular abnormalities. Corrective osteotomy has been shown to be associated with a very low rate of recurrent patellar luxation in cases with significant femoral varus or both femoral varus and torsional deformity (Swiderski and Palmer, 2007; Brower et al., 2017). Distal femoral osteotomy (DFO) is generally considered in large-breed dogs when the anatomic lateral distal femoral angle (aLDFA) is ≥102°, or when the femoral varus angle (FVA) is ≥12° (Swiderski and Palmer, 2007; Soparat et al., 2012; Brower et al., 2017).

†These authors contributed equally to this work and share first authorship.

*Corresponding author. Department of Veterinary Surgery, College of Veterinary Medicine, Konkuk University, 120 Neungdong-ro, Gwangjin-gu, Seoul 05029, Republic of Korea. Tel.: +82-2-450-4031.
E-mail: zypo@konkuk.ac.kr

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Three-dimensional (3D) printing in veterinary orthopaedics has been increasingly applied, particularly for the creation of patient-specific surgical guides to facilitate accurate corrective osteotomy (Kamishina et al., 2019). Advanced imaging modalities, such as computer tomography (CT), enable the generation of detailed three-dimensional bone models, which are essential for precise surgical planning. This approach enhances the accuracy of mechanical alignment correction, simplifies intraoperative procedures and contributes to reduced surgical time (Kamishina et al., 2019; Worth et al., 2019; Jeon et al., 2023).

Trochleoplasty modifies the morphology of the trochlear groove to establish sufficient depth and width, ensuring that approximately 50% of the patella extends above the trochlear ridges, while preserving maximal hyaline articular cartilage and enabling secure implantation of the osteochondral autograft (Johnson et al., 2001). However, trochleoplasty is not feasible where osteophytes and cartilage degradation have significantly compromised the integrity of the trochlear groove (Dokic et al., 2015).

Ridgestop is a surgical technique employed for augmenting the canine trochlear sulcus ridge. This technique has recently been shown to provide a technically simple alternative to trochleoplasty (Mills and Hargittai, 2020; Mills et al., 2024). It is primarily employed as a standalone procedure in cases of medial patellar luxation without accompanying angular deformities. In patients with more significant angular deformities, corrective osteotomies such as DFO or proximal tibial osteotomy (PTO) are necessary to achieve proper realignment of the quadriceps mechanism.

In cases where trochleoplasty poses a risk of implant exposure, particularly screws placed for DFO stabilisation, Ridgestop is the preferred alternative. It effectively minimises the risk of further cartilage damage while avoiding the complications associated with repeated trochleoplasty, providing a more effective and stable approach. Therefore, Ridgestop is considered a reliable alternative to trochleoplasty, even in cases with skeletal malalignment, while minimising the risk of further complications associated with trochleoplasty.

However, few cases have been reported on the Ridgestop technique and very few studies evaluate the results after surgical intervention. Moreover, there are no reports that discuss the simultaneous application of Ridgestop with corrective femoral and tibial osteotomies.

The objective of this case report is to describe the use of Ridgestop as a viable treatment option for recurrent patellar luxation in a dog after trochleoplasty, tibial tuberosity transposition and lateral imbrication. This case report highlights the clinical relevance of combining corrective osteotomy with Ridgestop implantation in the revision surgery of a grade IV MPL.

CASE DESCRIPTION

A 4-year-old, 3.9 kg, spayed female Bichon Frise was referred with lameness after MPL surgery at a local animal hospital. Intermittent non-weight bearing lameness of the left hind limb was observed during the general inspection. The physical examination indicated a grade IV MPL. Radiographic analysis revealed varus deformity of the distal femur and valgus deformity of the proximal tibia in the left hind limb, in addition to bilateral coxofemoral degenerative changes (Fig. 1). Mild pain was elicited during hip extension, with mild to moderate pain evident on palpation of the iliopsoas muscles. To exclude lameness associated with coxofemoral osteoarthritis and iliopsoas strain as the primary sources of lameness, extracorporeal shockwave therapy combined with laser therapy was administered once weekly for four weeks. Following treatment, pain on manipulation resolved; however, mild lameness and intermittent signs of gait abnormality persisted. Therefore, surgical correction for medial patellar luxation was considered to restore functional alignment following the failure of conservative management.

For the creation of the 3D-printed bone model, CT was conducted under general anaesthesia. The acquired Digital Imaging and Communications in Medicine (DICOM) images were imported into medical imaging software (3D Slicer; National Alliance for Medical Image Computing) for bone segmentation. The segmented bone models were exported as standard tessellation language (STL) files and imported into computer-aided design (CAD) software (3-matic 17.0; Materialise, Leuven, Belgium) to simulate osteotomy planes and generate patient-specific surgical guides.

CT-based 3D reconstructions demonstrated distal femoral varus deformity, proximal tibial valgus deformity, internal rotation of tibial tuberosity and bilateral moderate degenerative changes of coxofemoral joints. The femoral and tibial joint angles were calculated based on previously published parameters from other studies (Yasukawa et al., 2016; Lusetti et al., 2017). These CT-derived measurements were used to design customised 3D-printed osteotomy guides for DFO and PTO (Fig. 2). The closing wedge DFO guide was designed to simultaneously correct femoral varus and internal torsion by adjusting the aLDFA from 104° to 95° and the femoral anteversion angle from 3° to 18. Similarly, a closing wedge PTO was planned to correct both an increased TPA, reduced from 26° to 6° and an increased mMPTA, corrected from 100° to 95°, as both biplanar deformities shared a common centre of rotation of angulation (CORA) located on the proximal tibia in the oblique plane. Each patient-specific cutting guide for both the DFO and PTO incorporated four pin holes—two located proximally and two distally—to ensure secure fixation during bone cutting. For both the DFO and PTO, the reduction guides were fabricated with four pin holes. These pin trajectories allowed accurate repositioning of the osteotomy fragments in accordance with the preoperative surgical plan.

Patient-specific anatomical bone models, cutting guides and reduction guides were fabricated via rapid prototyping using a stereolithography (SLA) 3D printer (Form 4B; Formlabs Inc., Somerville, Massachusetts, USA) with BioMed White Resin (Formlabs Inc.), a biocompatible, medical-grade photopolymer. The printed components were washed in 99% isopropyl alcohol for 5 min and post-cured at 60 °C for 60 min, following the manufacturer's instructions.

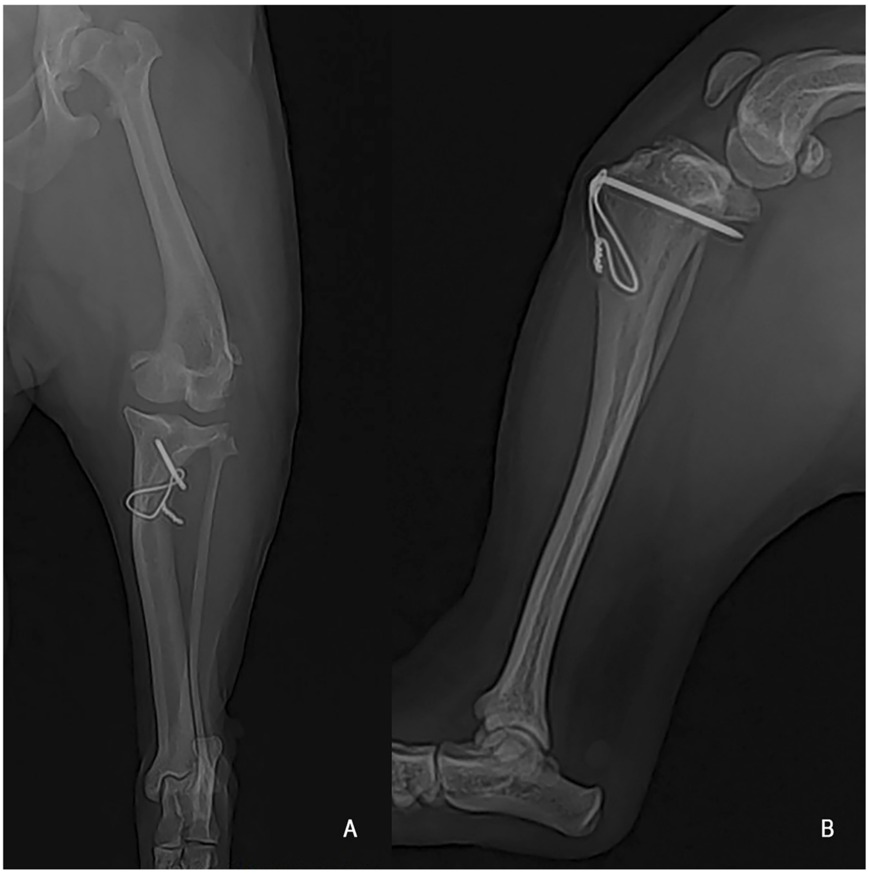

Fig. 1. Preoperative craniocaudal (A) and mediolateral (B) radiographs of the left stifle joint
Radiographs showed grade IV medial patellar reluxation, distal femoral varus and proximal tibial valgus in the left hind limb, which had previously undergone tibial tuberosity transposition (TTT), lateral imbrication and trochlear block recession (TBR)

Prior to surgery, premedication was carried out with butorphanol (0.1 mg/kg, IV) and acepromazine (0.01 mg/kg, IV). General anaesthesia was induced with propofol (8 mg/kg, IV) and was maintained with isoflurane delivered in oxygen. Cefazolin (25 mg/kg, IV, q 2 h) was administered prior to induction of anaesthesia. The patient was positioned in dorsal recumbency and was prepared for aseptic surgery. A standard lateral approach was used to expose the distal femur and stifle joints. After performing a craniolateral arthrotomy to assess the trochlear sulcus and articular cartilage, a femoral osteotomy guide was applied and secured with four 1.2 mm K-wires for alignment (Fig. 3A). The osteotomy was performed following the guide, and after completing the cuts, the guide was removed, leaving the K-wire in place. A femoral reduction guide was then applied to maintain proper alignment, and the osteotomy was stabilised with a laterally applied 1.5-mm DFO plate (ARIX VET system; Jeil Medical Co., Seoul, Republic of Korea) and screws (Fig. 3B, C).

A medial approach was executed on the left proximal tibia to correct the tibial valgus deformity, followed by elevation of the cranial tibial muscle and fascia using periosteal elevators. Using 3D-printed osteotomy guides, the tibial osteotomy was then carried out, ensuring proper alignment with the corrected tibial position as with the femur (Fig. 3D). After performing the osteotomy, the tibia was realigned, and the osteotomy site was stabilised using a 1.5-mm locking TPLO plate (ARIX VET system; Jeil Medical Co., Seoul, Republic of Korea) (Fig. 3E).

The Ridgestop implant was positioned after partial flexion of the stifle joint following lateral patellar luxation to maintain exposure of the medial trochlear ridge. The appropriate implant size was chosen according to the distance measured from the proximal end of the trochlear ridge to the condylar notch, and the guide was carefully positioned along the trochlear ridge to ensure precise alignment. The distal hole for fixation of the size 1.5 mm Ridgestop (Orthomed Ltd., Huddersfield, United Kingdom) was prepared using the appropriate drill guide and a 1.6 mm drill bit.

Subsequently, the most proximal hole was created using the drill guide to ensure proper alignment, drilling through both cortices. The drill was then withdrawn and replaced with a temporary fixation pin. Thereafter, a 1.6 mm hole was drilled through both cortices, and similarly, the drill was removed and replaced with another temporary fixation pin.

The most distal temporary fixation pin was removed, while the two proximal pins remained in place. After carefully removing the drill guide, the RidgeStop implant was

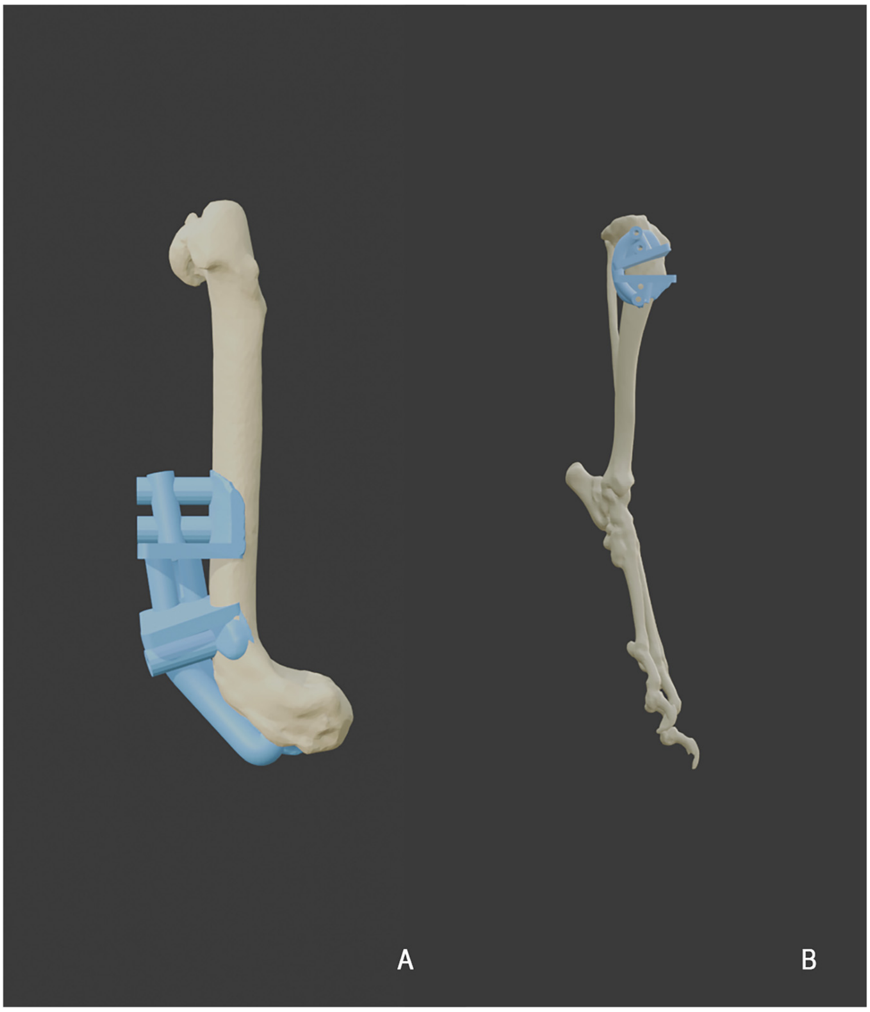

Fig. 2. Design of 3D-printed osteotomy guides for distal femoral (A) and proximal tibial (B) corrections
A distal femoral osteotomy guide designed for correction of varus and internal torsional deformities (A) and a proximal tibial osteotomy guide designed for correction of valgus and increased tibial plateau angle (B)

positioned over the pins and secured at the planned trochlear site.

The Ridgestop was firmly secured to the medial trochlear ridge using a 1.6-mm bicortical screw (Fig. 3F). Once all screws were securely placed, the position of the implant was confirmed, and the patella was assessed for proper tracking throughout the range of motion (ROM). Carprofen (4.4 mg/kg, SC, SID) was administered for postoperative analgesia.

Postoperative radiography revealed appropriate limb alignment and implant placement (Fig. 4). Surgical outcomes were evaluated radiographically by comparing pre- and postoperative angular parameters and physical examination results. For the DFO, correction was assessed based on changes in the aLDFA, which changed from 111° to 101°. For the PTO, realignment was evaluated using the TPA and the mMPTA. The TPA improved from 28° to 7° and the mMPTA changed from 110° preoperatively to 100° postoperatively.

During the 3-month postoperative period, the function of the affected limb showed progressive improvement without complications, including luxation or implant failure. The ROM in the operated limb was measured at 170°, which was consistent with 170° in the preoperative limb. At the time of the final follow-up examination, the patient showed satisfactory weight-bearing ambulation. No significant pain response was elicited on palpation of the previously operated stifle.

DISCUSSION

The patient presented for MPL revision surgery, exhibiting persistent, grade 4 lameness (Wangdee et al., 2013). Ridgestop was implemented to augment the medial trochlear ridge during the revision procedure. Distal femoral and proximal tibial osteotomies were performed using patient-specific 3D-printed osteotomy and reduction guides. Postoperatively, the patient showed no further signs of lameness and was able to achieve stable, weight-bearing ambulation.

In this case, trochleoplasty was not considered during the revision surgery for the following reasons. Repeat block recession on the articular surface could exacerbate

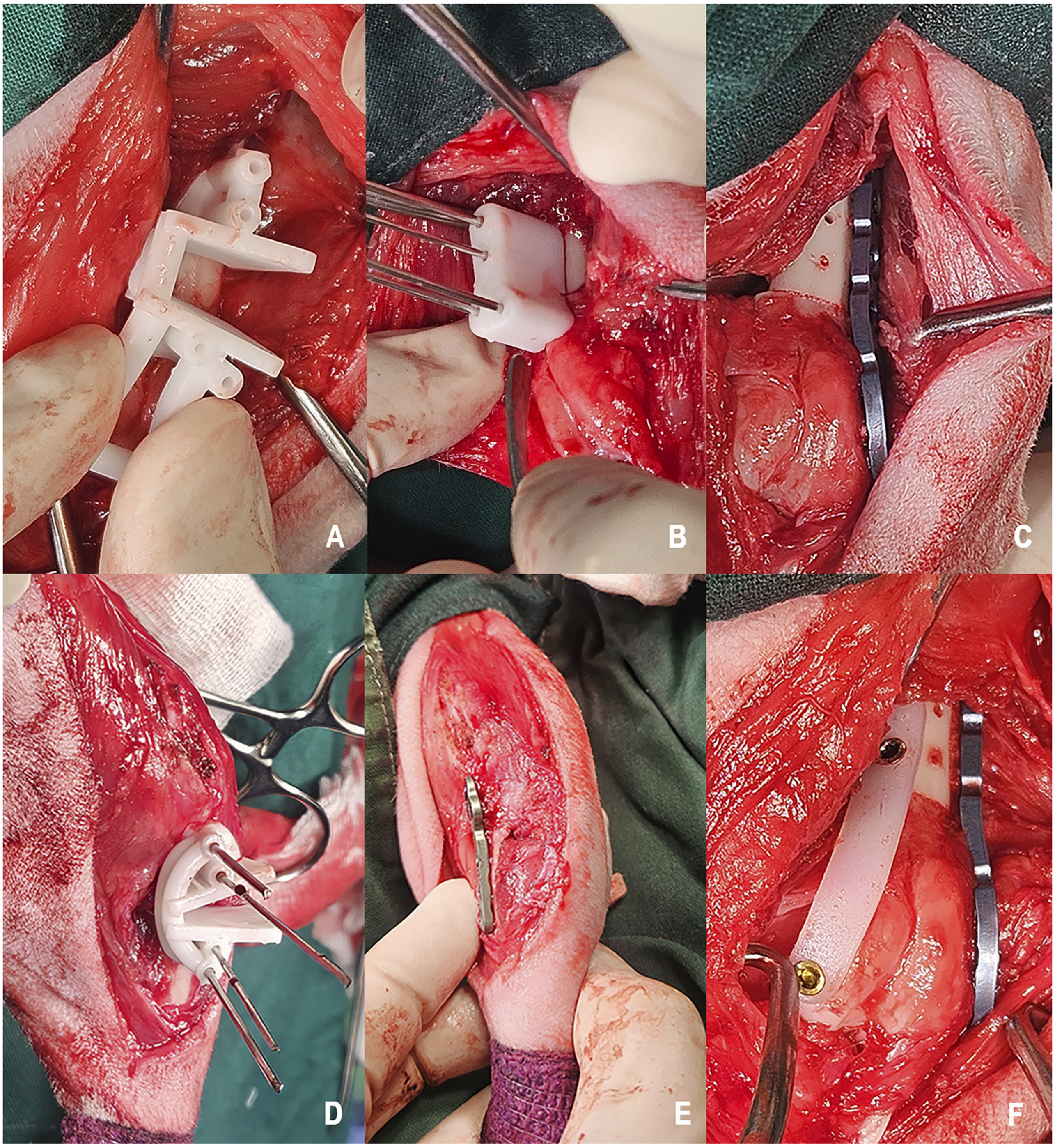

Fig. 3. Intraoperative photographs of distal femoral osteotomy (DFO) and proximal tibial osteotomy (PTO) using 3D-printed osteotomy and reduction guides and Ridgestop implantation
A 3D-printed osteotomy guide was positioned on the left distal femur to facilitate precise osteotomy (A), followed by application of a reduction guide to achieve accurate alignment of the femur (B) and subsequent stabilisation with a contoured bone plate (C). A similar approach was used for the proximal tibial osteotomy, with placement of a 3D-printed osteotomy guide (D) and TPLO plate fixation to maintain correction (E). A Ridgestop implant was applied to the medial trochlear ridge (F)

degeneration and accelerate osteoarthritis progression, thereby making it less suitable for revision surgery (Willauer and Vasseur, 1987; Roy et al., 1992). It is expected that Ridgestop will cause comparatively less articular cartilage damage. Unlike sulcoplasty, Ridgestop is reversible, and the implant can be easily removed if needed (Mills and Hargittai, 2020).

Additionally, in small dog breeds, repeated trochleoplasty is associated with an increased risk of femoral fracture (Chase and Farrell, 2010). Although the risk of femoral shaft fracture is minimised by plate fixation following DFO, the potential for ridge fracture remains high. The compromised condition of the medial trochlear ridge

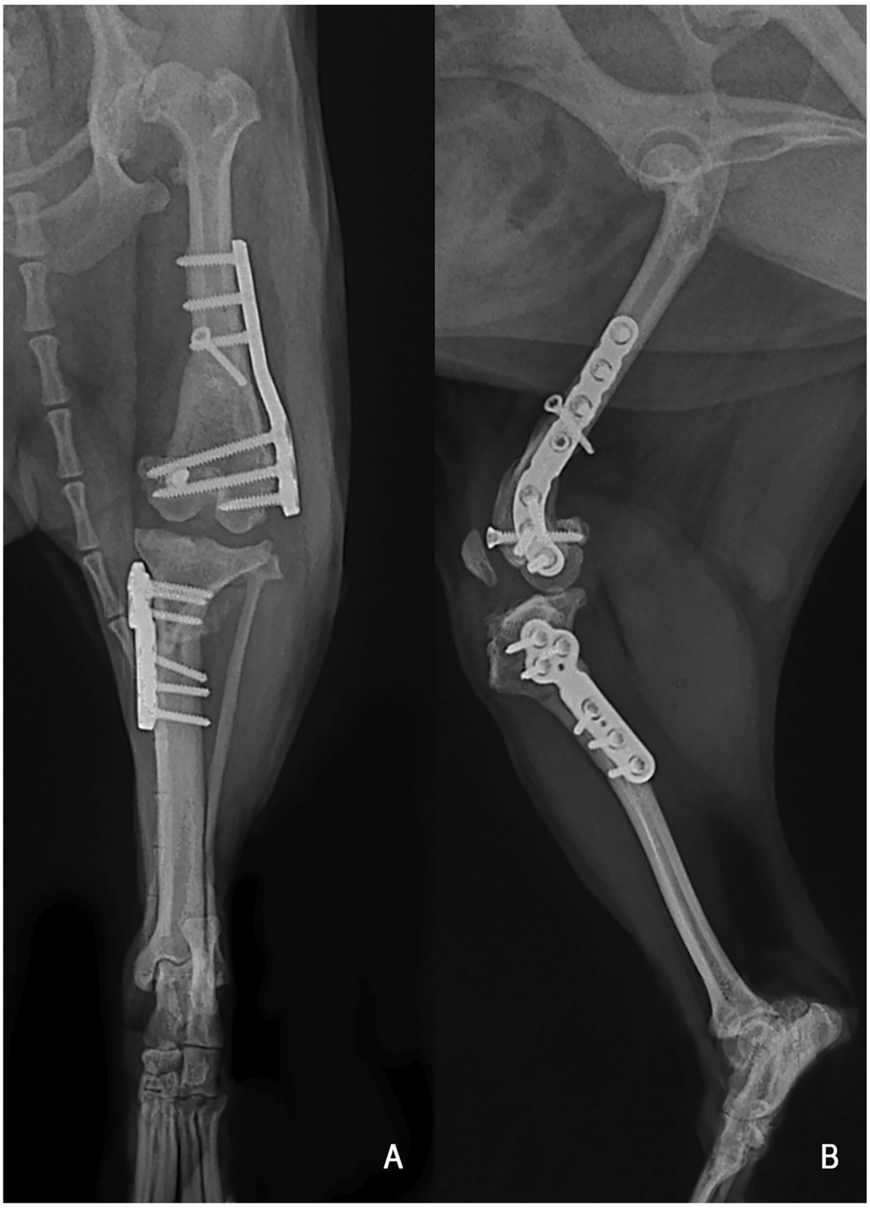

Fig. 4. Postoperative craniocaudal (A) and mediolateral (B) radiographs of the left stifle joint
At 3 months after surgery, the left hindlimb alignment was maintained, the Ridgestop implants remained stable, and there was no evidence of patellar reluxation

reduced the ability of the trochlear groove to withstand mechanical stress, thereby increasing the likelihood of fracture postoperatively.

Furthermore, as this patient underwent DFO during the revision surgery, trochleoplasty would have required careful avoidance of the pre-existing plate and screws, posing additional surgical challenges. If screw placement overlaps with the block recession site, there is a potential for the screw to protrude into the trochlear groove. In such cases, the screw direction must be adjusted caudally, which may compromise the stability of the plate-screw fixation.

In this situation, PGR can be considered as alternative surgical treatments. PGR has been described as a surgical option in dogs with severe femoro-patellar osteoarthritis (Dokic et al., 2015). In addition, PGR may also be indicated in cases of iatrogenic trochlear groove damage (Kim et al., 2016). Although PGR was considered, the patient's joint degeneration was not severe enough to require complete resurfacing. During arthrotomy, the joint capsule was assessed and the cartilage showed moderate trochlear degeneration. Although the cartilage surface exhibited localised fibrillation, discolouration and surface irregularities, there was no substantial cartilage loss or exposure of subchondral bone.

Thus, PGR was ultimately not performed, as the extent of trochlear cartilage degeneration was insufficient to warrant prosthetic replacement. Moreover, repeated trochleoplasty was not considered appropriate due to prior surgical manipulation and associated risk of iatrogenic damage.

In small-breed patients, the simultaneous application of both DFO and PGR can be challenging due to limited surgical access and implant size constraints. Although PGR can realign the quadriceps mechanism in cases with mild angular deformity, it is insufficient to address severe underlying limb deformities. In such cases, concurrent corrective osteotomy is required to achieve proper limb alignment (Dokic et al., 2015). In the current report, the severity of the underlying limb deformities necessitated realignment through DFO and PTO and the observed cartilage degeneration was not severe enough to require prosthetic resurfacing. Therefore, Ridgestop can be an appropriate option for patients with a shallow trochlear groove and when repeat block recession risks further cartilage damage. Additionally, it is suitable for cases where degeneration is not severe enough to require a PGR. Patellar stability was achieved without further trochlear damage by employing Ridgestop. Following surgery, satisfactory weight-bearing ambulation was achieved and no reluxation occurred during follow-up.

In this case, the accurate placement and alignment of both Ridgestop and the DFO plate were essential for the success of the procedure. A detailed surgical plan was developed using preoperative simulation with 3D-printed bone models derived from the patient's CT scan, ensuring precise positioning of both the DFO plate and Ridgestop. This preoperative simulation ensured optimal alignment and avoided interference with the DFO screws. The Ridgestop was positioned so that its axial aspect aligned with the curvature of the trochlear sulcus. Based on previous reports documenting concerns about complications such as screw loosening, Ridgestop was placed bicortically to enhance stability and minimise the risk of complications (Mills and Hargittai, 2020; Mills et al., 2024; Nicetto and Longo, 2024).

In small dog breeds, the currently available Ridgestop implant sizes, specifically the 1.5 and 2.0 mm options, exhibit a significant variation that may complicate implant selection. This variation can make it challenging to achieve an anatomically precise fit, which is critical for optimal patellar stabilisation. Implant size limitation can lead to inadequate mechanical support or excessive implant prominence, both of which can compromise the surgical outcome and hinder proper healing.

In cases of medial patellar luxation accompanied by angular deformities, the use of Ridgestop alone may be insufficient to achieve stable patellar tracking. In such cases, underlying alignment abnormalities, including femoral varus and torsional deformities, must be corrected concurrently to restore appropriate biomechanical function of the stifle joint. Failure to appropriately address underlying skeletal deformities may predispose to reluxation or implant-related complications, including implant failure, screw loosening, migration, or breakage, even after proper placement of the implant. Furthermore, Ridgestop may cause impingement of the patella or patellar tendon when underlying skeletal malalignment is not properly corrected. The relatively short duration of follow-up in this case limits the capacity to comment on the long-term development of osteoarthritis following Ridgestop implantation or on potential cartilage damage. Additionally, objective postoperative assessments, such as force plate analysis, were not performed. The intra-articular placement of the Ridgestop implant in the trochlear sulcus may exacerbate degenerative joint disease (DJD) through several mechanisms. These include trauma and debris from the implantation process, disruption of cartilage integrity leading to further degeneration, mechanical pressure on the joint capsule and potential degradation of the implant material itself, which could release particulate debris into the joint space. Therefore, a long-term clinical evaluation is warranted to assess potential complications following Ridgestop implantation, particularly the progression of degenerative osteoarthritis.

Preoperative radiographs were limited by rotational malpositioning, likely led to an overestimation of angular deformities such as femoral varus. Interestingly, while radiographic assessment suggested marked torsional and angular deformities, CT analysis revealed milder deviations than initially expected. This discrepancy is in accordance with prior reports demonstrating that radiographs, especially when taken with suboptimal positioning, may exaggerate the severity of femoral varus or other angular deformities (Dudley et al., 2006; Miles, 2016; Phetkaew et al., 2018).

Postoperative CT was not performed due to patient recovery status and financial constraints. However, postoperative radiographs confirmed notable improvement in alignment parameters, particularly in the frontal and sagittal planes. Compared to the preoperative values, the postoperative parameters approached normal alignment, indicating successful correction of the deformity. The postoperative alignment was evaluated based on the reference values reported in previous studies (Yasukawa et al., 2016; Phetkaew et al., 2018). The successful clinical outcome and radiographic improvement support the effectiveness of CT-based 3D surgical planning, even in the absence of postoperative CT confirmation. Consequently, the patient restored full weight-bearing function without recurrence of medial patellar luxation.

Ridgestop can be a valuable alternative in revision surgery for patients with progressive joint degeneration following primary trochleoplasty. The concurrent application of corrective osteotomy with Ridgestop implantation allowed for realignment of the extensor mechanism while preserving the trochlear cartilage and further studies are needed to evaluate the long-term stability and efficacy of Ridgestop.

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