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CASE REPORT

Semi-cylindrical recession trochleoplasty using 3D saw guides for canine patellar luxation

SB Park, JY Baek, SY Heo

Jeonbuk Animal Medical Center, Department of Veterinary Surgery, College of Veterinary Medicine, Jeonbuk National University, Republic of Korea
***Corresponding author, email:** syheo@jbnu.ac.kr*

Medial patellar luxation (MPL) is a common orthopaedic condition in dogs that often requires surgical intervention. Semi-cylindrical recession trochleoplasty (SCRT) is a promising technique; however, the adjustment increments of commercially available SCRT saw guides are limited. As an alternative, the effectiveness of patient-specific 3D-printed saw guides for SCRT was assessed for three small dogs with MPL. An eight-year-old Chihuahua (6 kg) and a ten-year-old Maltese (5 kg) with MPL Grade 3, as well as a five-year-old Cocker Spaniel (10 kg) with MPL Grade 4, were included in this study. Preoperative computed tomography (CT) scans confirmed no angular bone deformities in the three dogs. The animals underwent SCRT using 3D-printed patient-specific saw guides, which allowed for customised adjustments to the trochlear groove depth, overcoming the 1.5 mm increment limitation of commercially available guides.

Digital imaging and communications in medicine (DICOM) images from the CT scans were converted into stereolithography (STL) files and Fusion 360 was used to design the saw guides, which were then 3D-printed for use with SCRT under general anaesthesia. Postoperative orthopaedic examinations and radiographs performed two weeks after surgery showed that two of the dogs had no pelvic limb lameness or patellar reluxation. One patient did not achieve complete MPL correction, despite the appropriate trochlear groove depth being obtained, due to extrinsic factors.

The 3D-printed patient-specific saw guides facilitated precise customisation of the trochlear groove depth during SCRT in the dogs analysed in this study, highlighting the potential to enhance surgical accuracy. Therefore, this approach has the potential to advance MPL treatment by enabling greater surgical precision and addressing challenges associated with operative time and technical difficulty. Further studies with larger sample sizes and standardised protocols are needed to fully assess the clinical benefits and cost-effectiveness of this method.

Keywords: semi-cylindrical recession trochleoplasty, 3D printing, medial patellar luxation, dog, saw guide

Introduction

Medial patellar luxation (MPL) is a common orthopaedic condition affecting the pelvic limbs of dogs (Blackford-Winders et al. 2021; Di Dona et al. 2018). This condition typically arises due to a malalignment of the quadriceps mechanism and an insufficient depth of the femoral trochlea (Di Dona et al. 2018). Surgical procedures vary based on the underlying cause, and if multiple causative factors are involved, a combination of techniques, such as tibial tuberosity transposition, distal femoral osteotomy, medial desmotomy, lateral imbrication, trochleoplasty, and ridgestop procedure is often required (Arthurs et al. 2006; Deom et al. 2023). Trochleoplasty is generally indicated when the femoral trochlea lacks adequate depth (Lee et al. 2020; Linney et al. 2011).

Common trochleoplasty techniques include trochlear block recession (TBR) and trochlear wedge recession (TWR) (Linney et al. 2011; Blackford-Winders et al. 2021). Cadaveric research has shown that TBR is superior to TWR in trochlear depth, patellofemoral contact forces and reduced reluxation outcomes (Deom et al. 2023; Choi et al. 2023). However, TBR poses technical challenges, especially in smaller dogs, due to the risk of osteochondral block fractures and trochlear ridge fractures during the procedure (Linney et al. 2011).

A promising alternative has recently been introduced (semi-cylindrical recession trochleoplasty [SCRT]) (Blackford-Winders et al. 2021). Similar to TBR, SCRT preserves the cartilage of the femoral trochlea, as the SCRT saw features a hollow cylindrical design. In addition, a pilot study reported that SCRT was less technically demanding and produced comparable short-term outcomes and complication rates to those achieved with TBR (Deom et al. 2023). However, commercially available SCRT saw guides can only adjust the trochlear groove depth in 1.5 mm increments, as the insertion holes for K-wires, used to adjust the guide's position for groove depth modification, are spaced 1.5 mm apart. This limitation is often insufficient when working with small dogs (Blackford-Winders et al. 2021).

To address this limitation, we designed patient-specific 3D-printed saw guides that enable precise customisation of the desired trochlear groove depth. This case series reviewed three cases of dogs treated with SCRT using these guides and evaluated the benefits of this approach.

Patient presentation

Three castrated male dogs, an eight-year-old, 6 kg Chihuahua (Case 1), a ten-year-old, 5 kg Maltese (Case 2), and a five-year-old, 10 kg Cocker Spaniel (Case 3) were referred to the Jeonbuk Animal Medical Center (Jeonbuk National University, College of

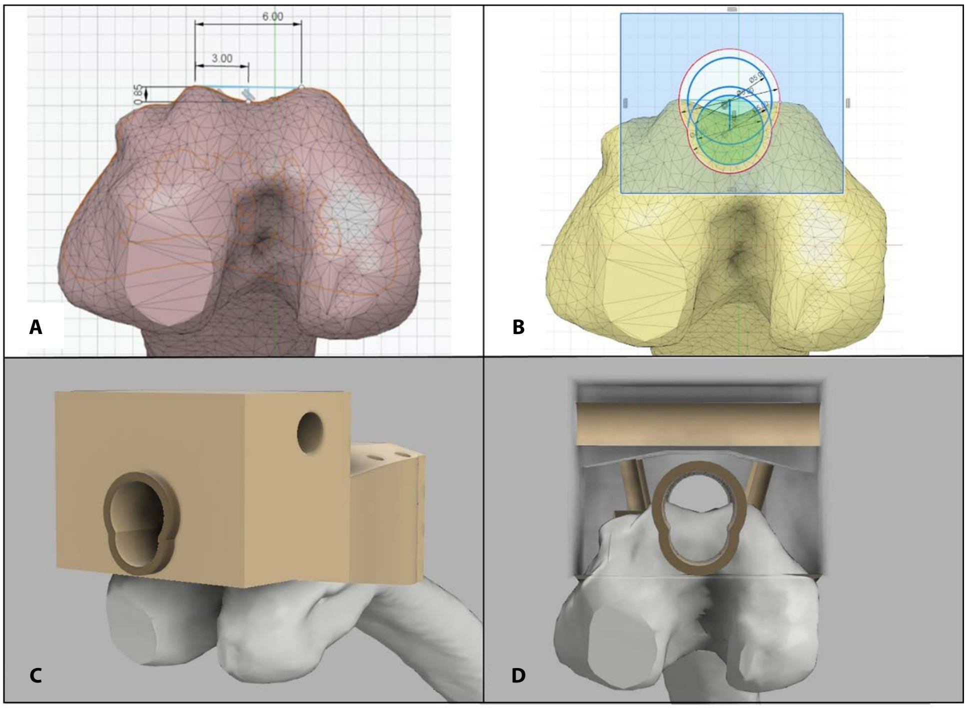

Figure 1: (A) The initial process of designing a patient-specific saw guide using 3D-planning software. (B) The second guide hole located below and overlapping the first hole (green circle). (C) 45-degree oblique view of the guide. (D) Orthographic projection view of the guide from the front.

Veterinary Medicine, Jeollabuk-do, Korea) with a history of MPL. Cases 1 and 2 were diagnosed with Grade 3 MPL, while Case 3 was diagnosed with Grade 4 MPL. The preoperative radiographs and CT scans (Alexion TSX-034A, Canon Medical Systems; Tokyo, Japan) revealed no angular bone deformity in any of the three cases.

Surgical planning and 3D guide designing

Digital imaging and communications in medicine (DICOM) images obtained from the CT scans were converted into stereolithography (STL) files using Mimics medical software (Materialise, Leuven, Belgium). We then designed a patient-specific saw guide for SCRT using these STL files with Fusion 360 (Autodesk, California, United States of America). The first osteotomy hole was designed to create an osteochondral block. To ensure the block was of appropriate size, we measured the distance between the highest points of the trochlear ridges and selected the SCRT saw diameter that was closest to, but did not exceed, this measurement (Figure 1A).

The second osteotomy hole was designed to create a trochlear groove of appropriate depth. To achieve a groove depth equivalent to 50%–60% of the patellar thickness, the second osteotomy line was positioned below the centre of the first osteotomy line at a depth determined by the additional groove depth required, based on the patient's trochlear groove (Figure 1B).

The saw size for the second osteotomy was 1 mm smaller than the first saw. This adjustment accounted for the approximately 1 mm of bone loss that occurs due to the 0.5 mm thickness of the saw blade during the osteotomy process. Using a saw that was 1 mm smaller ensured proper press-fit of the osteochondral block formed during the first osteotomy. After designing osteotomy holes, we created spaces in the guide to avoid interference with structures such as the long digital extensor tendon. The

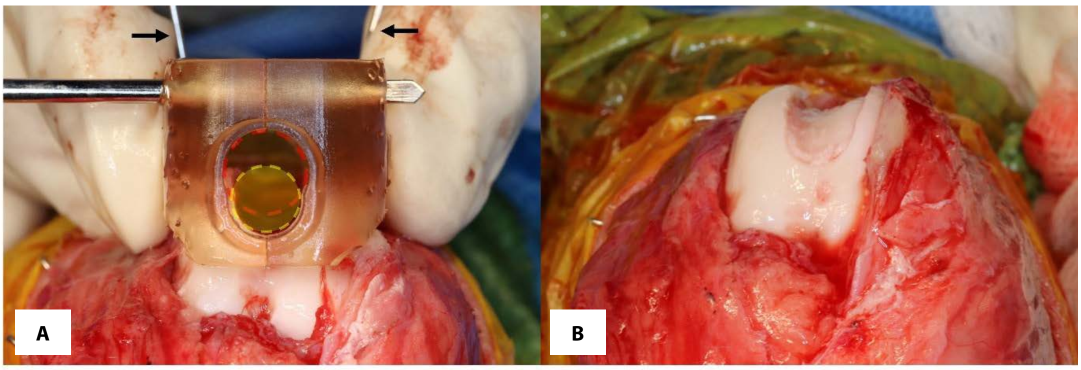

Figure 2: (A) The saw guide was securely fixed to the trochlear groove using two K-wires (black arrows). Osteotomies were performed using the upper guide hole (red circle) and the lower guide hole (yellow circle). (B) Appropriate trochlear groove depth and press-fit of the osteochondral block were confirmed intraoperatively.

guide was 3D-printed using MSLA 3D printer Pixel one (Zerone, Siheung, Korea) medical grade 2 resin ZMD-1000B Clear SG (Dentis, Daegu, Korea) (Figures 1C, 1D).

Surgical technique

All surgeries were performed under general anaesthesia. For prophylactic antibiotics, amoxicillin-clavulanate (13.75 mg/kg IV, Amocla Injection, Kuhnil Corp., Korea) was administered. Premedication included midazolam (0.2 mg/kg IV, Midazolam Injection, Bukwang Pharm, Korea) and fentanyl (1 mcg/kg IV, Fentanyl Citrate Injection, Myung Moon Corp., Korea). Induction was performed using propofol (6 mg/kg IV, Freepol-MCT Injection, Daewon Pharm, Korea), and maintenance anaesthesia was achieved with sevoflurane (Sevofran Liquid for Inhalation, Hana Pharm, Korea) in combination with 100% oxygen. Intraoperative and postoperative analgesia was provided through fentanyl CRI (1 mcg/kg/h IV). A lateral parapatellar approach was used in all cases. The saw guide, which had been sterilised using ethylene oxide (EO), was securely fixed to the trochlear groove with two 1.0 mm or 1.2 mm Kirschner wires at the distal part of the femoral diaphysis (Figure 2A). Two osteotomies were performed: the first osteotomy, to create the osteochondral block, was performed by inserting a 6 mm or 5 mm SCRT saw into the upper hole of the guide. The second osteotomy, to deepen the trochlear groove, was performed by inserting a 5 mm or 4 mm SCRT saw into the lower hole of the guide. Intraoperative confirmation of the proper press-fit of the osteochondral block was obtained (Figure 2B).

Postoperative management and outcomes

Standard protocols were employed for postoperative rehabilitation, and orthopaedic examinations and radiographs were performed 2–16 weeks post-surgery. Cases 1 and 2 showed no pelvic limb lameness, patellar reluxation, or other complications. Based on the lameness grade scale described by Witte and Scott (2011), the degree of lameness in these cases was determined to be Grade 0. Despite achieving an appropriate trochlear groove depth, complete correction of MPL was not achieved in Case 3 due to factors unrelated to groove depth (Figure 3). However, less severe lameness was noted in Case 3 after surgery. Preoperatively, the lameness was assessed as Grade 4, but it improved to Grade 2 postoperatively.

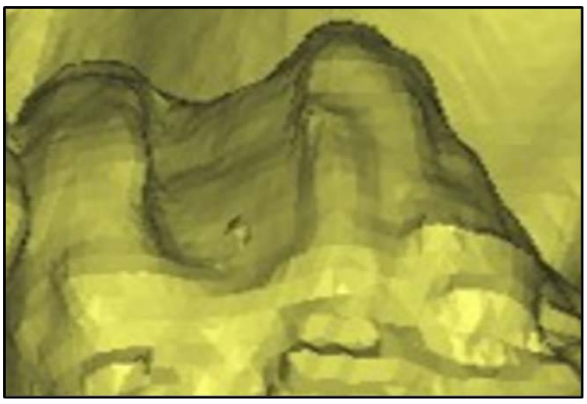

Figure 3: In Case 3, postoperative CT scans confirmed the appropriate trochlear groove depth was achieved and the press-fit of the osteochondral autograft was adequate. The patella was not positioned above the groove due to other factors contributing to MPL onset.

Discussion

Our study provided relevant findings and implications for future research and clinical practice. Our patient-specific SCRT saw guides enabled precise customisation of the trochlear groove depth as opposed to the 1.5 mm incremental limit of commercial guides (Blackford-Winders et al. 2021). This level of precision is particularly beneficial when operating on very small dogs where minor deviations can have considerable impacts on surgical outcomes (Linney et al. 2011). The tailoring of the groove depth, guided by measurements of the trochlear ridges and the patellar thickness for each patient, contributed to the successful creation of grooves that enhanced patellar tracking and stability in all three cases. This demonstrates how the limitations of commercially available SCRT saw guides, which only allow groove depth adjustments in 1.5 mm increments, can be overcome using 3D-printed patient-specific saw guides. While further studies are needed to validate these findings, this method shows potential for improving surgical precision and outcomes, particularly in small-breed dogs where tailored adjustments are crucial (Blackford-Winders et al. 2021).

While this study did not directly compare surgical times, previous reports suggest that SCRT may require less overall surgical time than TBR due to its simplified technique and reduced risk of block fracture (Blackford-Winders et al. 2021). Trochlear block recession (TBR) has been reported to be technically challenging and time-consuming due to the need for precise undermining of the osteochondral block, particularly for small dogs with a high risk of block fracture (Linney et al. 2011; Johnson et al. 2001). Although this case report did not directly compare commercially available SCRT guides with 3D-printed patient-specific guides, the latter offers notable advantages. Unlike commercially available guides, 3D-printed patient-specific guides allow both osteotomies to be performed without the need to readjust the guide's position. By securely aligning with the patient's specific anatomical characteristics, these guides simplify the osteotomy process, enhance surgical precision, and potentially reduce surgical time. Additionally, this approach may lower the technical difficulty of SCRT compared to using commercially available guides. Deom et al. (2023) reported similar findings, whereby SCRT simplified the procedure without compromising the outcome.

Previous studies have demonstrated that SCRT provides superior patellofemoral contact pressure outcomes compared to TBR (Choi et al. 2023; Linney et al. 2011). Although this study did not involve a direct comparison between SCRT and TBR, the clinical outcomes observed may reflect the benefits of SCRT as previously reported in the literature (Blackford-Winders et al. 2021). Specifically, Choi et al. (2023) noted that while both procedures effectively reduce the elevated contact pressure associated with trochlear hypoplasia, SCRT achieves a more uniform reduction across the joint. In contrast, TBR has been reported to result in elevated distal contact pressures, likely due to its osteotomy design. However, direct comparative studies with larger sample sizes are necessary to further validate these differences and confirm the clinical significance of these findings (Lee et al. 2020).

Despite achieving a well-formed trochlear groove, the MPL correction in one of our cases (Case 3) was incomplete due to extrinsic factors unrelated to the groove depth, such as tibial rotation and quadriceps mechanism misalignment. Although tibial tuberosity transposition (TTT) was required in combination with trochleoplasty to address the alignment issue, it was not performed due to the owner's financial constraints and preference for a less extensive surgical approach. These factors contributed to the incomplete correction, although the patient showed improvement to Grade 3 MPL and reduced lameness postoperatively. This result underscores the complexity of MPL correction and the need to address all contributing factors (Linney et al. 2011; Dunlap et al. 2016). Blackford-Winders et al. (2021) stated that achieving the desired trochlear groove depth was insufficient for complete MPL correction. A comprehensive approach must be used when treating MPL that considers all anatomical and biomechanical factors (Isaka 2022).

There are several limitations to our study. The design of the guides evolved throughout the study, leading to slight variations, and the small sample size and inconsistent follow-up durations limited the generalisability of our findings. Furthermore, the study did not include a direct comparison with commercially available guides or other surgical techniques such as TBR. The time and cost associated with designing and producing patient-specific guides and the inherent learning curve also need to be addressed. Prospective studies with standardised guide designs and protocols are necessary to fully assess the clinical benefits and cost-effectiveness of this approach.

Conclusion

SCRT has been reported to offer several advantages over TBR. However, commercially available SCRT saw guides have limitations, such as adjustments restricted to 1.5 mm increments, which can be challenging in small dogs. Using a 3D-printed patient-specific saw guide, we addressed these limitations and achieved satisfactory outcomes. Further studies with larger sample sizes and direct comparisons to TBR and commercial guides are needed.

Ethics approval and consent to participate

Ethics approval was obtained from the University of Pretoria Faculty of Veterinary Medicine Research Ethics Committee (REC136-24).

As part of a general anaesthesia and surgery consent form, owner consent to use clinical data for potential publication or teaching was obtained upon entrance at author's animal medical centres.

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Conflict of interests

The authors declare that they have no competing interests.

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Ethical approval

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

All institutional and national guidelines for the care and use of laboratory animals were followed.

ORCID

SB Park https://orcid.org/0009-0004-1969-728X

JY Baek https://orcid.org/0009-0008-7102-9755

SY Heo https://orcid.org/0000-0002-7733-3263

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