Article published online: 2023-10-31

Trochlear Ridge Prostheses for Reshaping Femoral Trochlear Ridges in Dogs with Patellar Luxation

Tommaso Nicetto[1] Federico Longo[2]

[1] Diagnostica Piccoli Animali, Clinica Veterinaria Pedrani, Vicenza, Italy
[2] Clinic for Small Animal Surgery, University of Zurich, Zurich, Switzerland

Address for correspondence Tommaso Nicetto, DVM, PhD, Diagnostica Piccoli Animali, Clinica Veterinaria Pedrani, Vicenza, Italy (e-mail: tommaso.nicetto@gmail.com).

Vet Comp Orthop Traumatol 2024;37:98–106.

Abstract

Objectives To describe the implant characteristics and surgical application of a custom-made trochlear ridge prosthesis (TRP) and to report clinical outcomes in dogs affected by patellar luxation treated with TRP.

Study design Dogs affected by patellar luxation underwent computed tomography. A specific canine bone anatomical replica, a cutting guide, and a TRP were designed and provided for surgery. Surgical records, clinical and radiographic reassessments, complications, pre- and postoperative lameness, type and degree of patellar luxation, and TRP and patellar position after surgery were reviewed. Clinical outcomes were defined as full, acceptable, or unacceptable function.

Results The TRP was implanted in 60 femoral trochleae: 48 unilateral and 12 bilateral. Successful correction of patellar luxation was achieved in 59/60 cases. TRP was applied with other surgical techniques in 36/60 of the cases and as the only surgical procedure in 24/60 cases. Overall, three complications were observed: two minor and one major (patellar luxation recurrence). Neither implant loosening nor infection was observed. The mean radiographic follow-up was 3.8 months. At the time of the final follow-up, 57/60 cases were scored as fully functional.

Conclusion The TRP application either alone or in combination with other surgical techniques allowed for correction of patellar luxation and improvement in preoperative lameness with nominal complications. TRP could represent a potentially reliable alternative to trochleoplasty.

Keywords
- patellar luxation
- trochleoplasty
- stifle
- dog
- femoral trochlear groove

Introduction

Patellar luxation is one of the most commonly diagnosed orthopaedic diseases in dogs.[1,2] It has been reported that patellofemoral joint congruency may alter the femoral trochlear groove depth during the skeletal development of dogs.[3] Quite often, a shallow femoral trochlear groove is secondary to patellar maltracking and patellar luxation.[3] However, more rarely a shallow femoral trochlear groove may be primarily associated with a recurrent patellar luxation.[4]

Restoring normal hindlimb alignment is often required to treat patellar luxation in dogs.[5–10] Trochleoplasty is a common procedure that aims to improve the accommodation of the patella within the femoral trochlear groove.[8,11] Complications, such as osteochondral wedge dislodgment or fracture of the trochlear ridge, have been described.[9,12–15]

received January 3, 2023
accepted after revision September 26, 2023
article published online October 31, 2023

DOI https://doi.org/10.1055/s-0043-1776331.
ISSN 0932-0814.

Other surgical procedure such as patellar groove replacement (PGR; Kyon, Zurich, Switzerland) and Ridgestop (Orthomed, Huddersfield, United Kingdom) have been proposed in dogs[16,17] and cats[18,19] to reshape the whole femoral trochlea or the femoral trochlear ridge, respectively. Ridgestop consists of a polyethylene ridge, which is held in place with cortical screws. Clinical data of Ridgestop are currently very limited as only one case series (four cats) was published.[19]

The authors of the present study reported recently as a short communication[20] a patient-specific custom-made implant that aims at improving the accommodation of the patella within the femoral trochlear groove via augmentation of the buttress support of the femoral trochlear ridges. Trochlear ridge prosthesis (TRP) is a titanium implant developed from three-dimensional (3D)-reconstructed computed tomographic (CT) images of the femoral trochlea and produced by direct metal laser sintering technology (►**Fig. 1**).

To date, we are unaware of studies reporting the use of a custom-made implant designed to augment the height and reshape the profile of the femoral trochlear ridges. Therefore, the purpose of this study is to (1) describe the key features of the TRP and the surgical technique and (2) report clinical outcomes and complication rates following the implantation of TRP in dogs affected by patellar luxation. The success for correction of patellar luxation was defined based on postoperative clinical and radiographic outcomes.

Materials and Methods

CT Examination

A CT was the first step to manufacture TRP. For each dog, contiguous CT images (Toshiba Asteion S4, Toshiba Medical Systems Europe, Amsterdam) were obtained and a DICOM software (Osirix version 2.7, Pixmeo SARL, Geneva, Switzerland) was used to analyze the femoral trochlear groove.

The femoral trochlear morphology was evaluated and the femoral trochlear groove depth and patellar craniocaudal thickness were quantified using a described methodology.[21] Once the femoral trochlear measurements were finalized, a stereolithographic (STL) file was created for further imaging processing.

Implant Design and Manufacture

Three software programs (Mimics 20.0 and Magics 23.01, Materialise NV, Leuven Belgium; Geomagic 2019.1.67-3D, Systems, Inc., United States) were used for the design and manufacture of (1) an anatomic replica of the femoral trochlea of the affected limb, (2) a cutting guide, and (3) the TRP.

The luxated patella was moved within the femoral trochlear groove via software manipulation (►**Fig. 2A, B**). The femoral trochlear ridges were replaced (►**Fig. 2C**) with TRP. From the sagittal view, the height of the TRP was designed to cover 40% of the patellar craniocaudal thickness (►**Fig. 2D**).

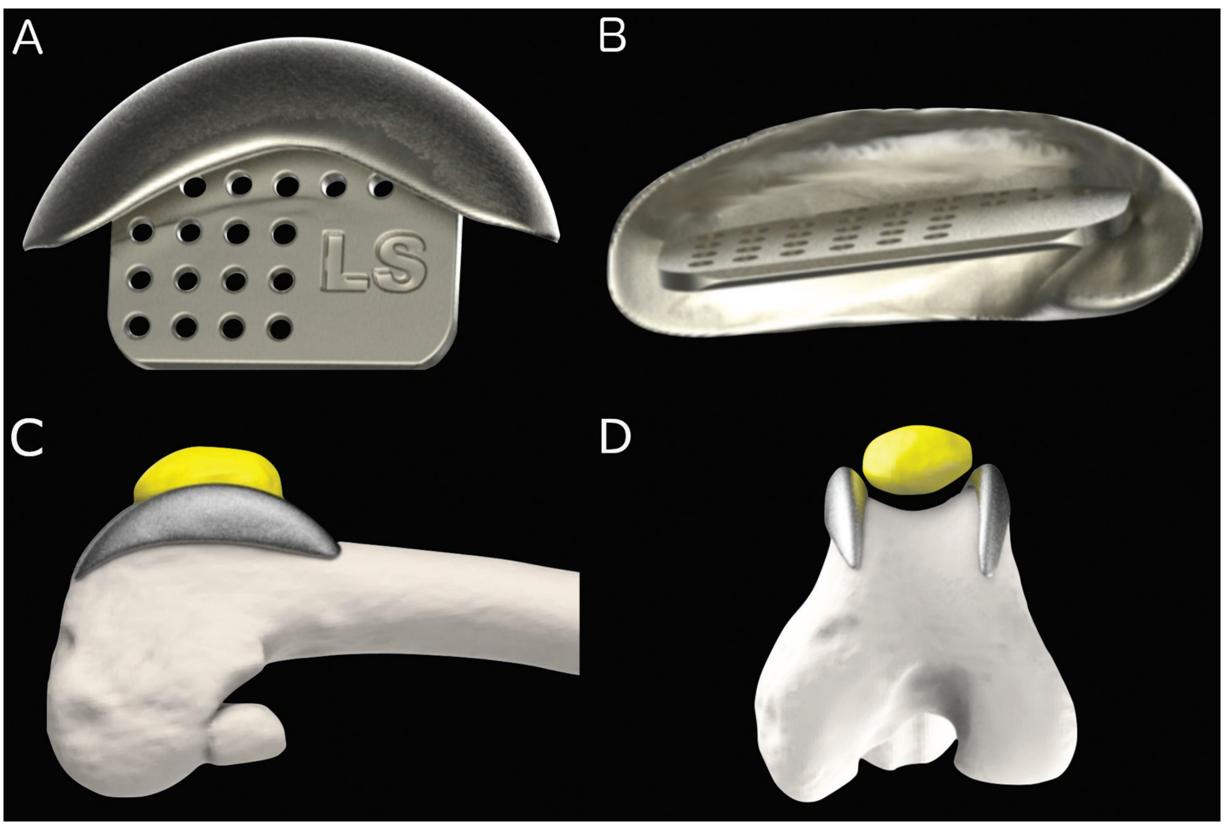

Fig. 1 Lateral (**A**) and caudal views (**B**) of the trochlear ridge prosthesis. The lateral view shows the extraosseous component and the intraosseous component. Computerized design of the trochlear ridge prosthesis (**C, D**). The patella is positioned into the trochlear groove using computer software manipulation, and the extraosseous component is designed to cover 40% of the patellar thickness in the sagittal plane (C).

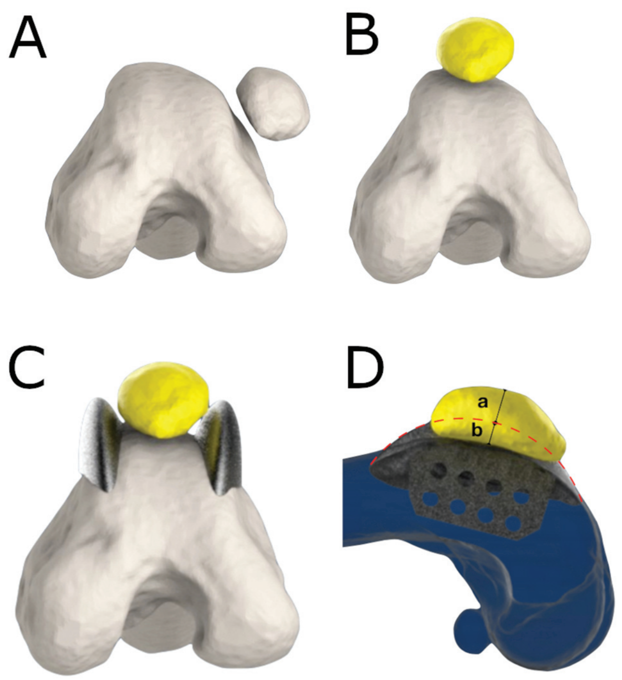

Fig. 2 Software manipulation to design the height of the trochlear ridge prosthesis (TRP): transverse view of the three-dimensional femoral trochlea reconstruction with the patella medially luxated (**A**). Transverse view of the three-dimensional femoral trochlea reconstruction with the patella repositioned with the femoral trochlear groove after software manipulation (**B**). Transverse view of the three-dimensional femoral trochlea reconstruction after replacement of the native femoral trochlear ridge with TRP (**C**). Assessment of the TRP height in the sagittal plane. The dashed red line indicates the TRP profile. Segment "a" must be 60% of the patellar craniocaudal thickness in the sagittal plane. The TRP must cover 40% of the patellar thickness in the sagittal plane (segment "b") (**D**).

TRP has an extraosseous component, which augments the trochlear ridge, and an intraosseous component, which has a rectangular press-fit design to promote osteointegration (►**Figs. 1** and **3**).[22] The articular surface of the extraosseous component is curved and smooth which allows the surrounding soft tissues to slide over it. Mirror finishing is employed on the extraosseous surface of TRP. The bone surface of the extraosseous portion of the TRP is concave to fit the contour of the femur (►**Fig. 1**).

The intraosseous component is a rough rectangular plate perforated with several small holes each with a diameter of 0.7 mm (►**Fig. 1**), which facilitates osteointegration.[17–19] The thickness of the plate is based on dog size and ranges from 0.5 to 1 mm. The TRP plates are parallel to each other and perpendicular to the femur in the frontal plane. Furthermore, the depth of the plate is designed to avoid contact with the endosteal surface of the caudal cortex of the distal femur (►**Fig. 3**).

The femoral trochlear anatomic replica and the cutting guides are also manufactured (►**Fig. 4**). TRP is designed to be complementary to the profile of the trochlear ridge; thus, TRP must be applied in a specific site of the femoral trochlea. The cutting guide was designed to accurately match the cranial surface of the distal femoral epiphysis and to be positioned in the most prominent aspect of the femoral trochlear ridges. The cutting guide ends proximally with two wings that wrap around the distal femoral metaphysis. There are two slots in the guide that allow for executing parallel osteotomies, perpendicular to the femur in the frontal plane (►**Fig. 4**). The cutting guide slots are designed to be 0.5 mm wider than the saw blade thickness.

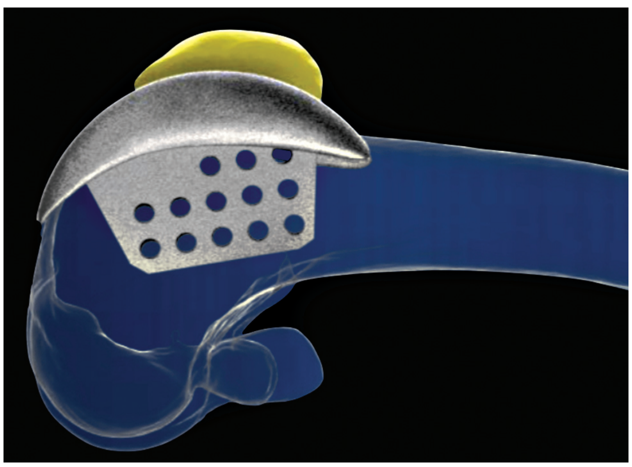

Fig. 3 Image showing the trochlear ridge prosthesis. The femur is transparent to show that the intraosseous component (perforated rectangular plate) of the implant does not touch the endosteal surface of the distal femoral caudal cortex.

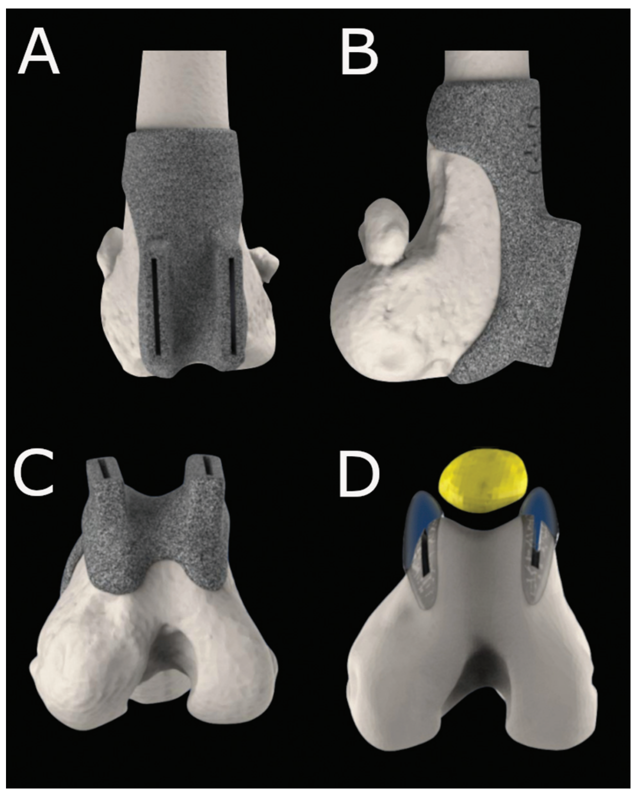

Fig. 4 Images of the cutting guide in frontal (**A**), sagittal (**B**), and transverse planes (**C, D**). TRP in image (D) is transparent to indicate where the two linear cuts are made in the cranial surface of the distal femur. The osteotomies are performed at the top of the femoral trochlear ridges, parallel to each other and perpendicular to the femur.

With regard to implant printing, the femoral anatomical replica and the cutting guide were made of polyamide and printed with a 3D printing machine (Jet Fusion 3D 4200, HP, Palo Alto, California, United States), whereas the TRP was made of titanium (alpha-beta titanium-alloy, Grade 5) and was printed using a 3D metallic printer (Truprint 2000, Trumpf, Ditzingen, Germany).

Medical Records and Inclusion Criteria

This study was approved by a local ethical and deontological committee. Informed consent was submitted to the owner before TRP surgery.

Surgical records of dogs affected by patellar luxation that underwent TRP surgery were retrieved from 2016 to 2022 in the computerized database of a veterinary clinic (*Diagnostica Piccoli Animali, Clinica Veterinaria Pedrani, Vicenza, Italy)*.

Data were reviewed to record signalment, history, and findings of the orthopaedic examination. A pre- and postoperative lameness evaluation was performed while the dog was walking and trotting and scored using a visual scale of 5 grades.[23] The direction (medial or lateral) and degree (Putnam scale) of patellar luxation,[24] femoral and tibial alignment, surgical techniques performed to treat patellar luxation, and complications were also recorded.

Hindlimb alignment was evaluated preoperatively with either orthogonal radiographic projections or with CT using literature reference values.[25–31] Postoperatively, hindlimb alignment was assessed exclusively with an orthogonal radiographic study.

The inclusion criteria for the study were (1) the use of a TRP in dogs with patellar luxation, (2) a CT study for the measurements, (3) a clinical and radiographic follow-up of at least 2 months, and absence of chondral erosions of the femoral trochlear groove.

The comprehensiveness of the follow-up was assessed according to the literature guidelines.[23] Briefly, a perioperative follow-up was defined within 3 months, a short-term follow-up between 3 and 6 months, a mid-term follow-up between 6 and 12 months, and a long-term follow-up after 12 months.[23]

Complications were defined as intraoperative and postoperative as well as minor, major, and catastrophic.[23]

Surgery

A parapatellar lateral or medial surgical approach was performed depending on if and which additional surgical procedure was performed with TRP.[32]

Once the cranial articular surface of the distal femur was exposed, the soft tissues were dissected from the cranial surface of the distal femoral metaphysis to allow the placement of the cutting guide (►**Fig. 4**). The guide was kept stable by sliding the wings over the femur. Proper positioning of the cutting guide was assessed intraoperatively by applying the cutting guide onto the femoral anatomic replica. The distance from the guide to the proximal aspect of the femoral intercondylar notch was measured on the femoral anatomic replica (►**Fig. 5B** and **6**). The same distance was used to evaluate proper positioning of the cutting guide onto the femur (►**Fig. 5C**).

Additionally, the depth of each osteotomy was assessed in the femoral anatomic replica. A graduated saw or a depth-stop was used to measure the maximal depth of the osteotomies (►**Fig. 5**). The two osteotomies were performed with a motorized oscillating saw (DePuy Synthes, Oberdof, Switzerland). The thickness of each osteotomy was slightly less than that of the plate.

The cutting guide was removed, and a number 11 scalpel blade was inserted in each osteotomy to remove small remnants of subchondral bone to facilitate the insertion of the TRP intraosseous component.

Final TRP insertion was achieved by applying gentle pressure on the implant with a Teflon hammer (Securos, Fiskdale, Massachusetts, United States). The hammer is soft and does not scratch or dent the prosthesis surface (►**Fig. 6**). The patella was positioned within the femoral trochlear groove, and patellar tracking was assessed by executing stifle flexion and extension with concurrent inward and outward rotation of the pes while the joint capsule was still open.

Fascia release or imbrication and femoral and/or tibial corrective osteotomies were additionally performed, if needed, to correct hindlimb malalignment.

Radiographic Outcomes

Femoral and tibial postoperative radiographs were obtained immediately after surgery to assess patellar and TRP positioning and evaluate hindlimb alignment (►**Fig. 7**).[25] Whenever femoral torsion was corrected, the geometrical biplanar technique was used to evaluate postoperative torsion correction.[31] Tibial tuberosity position relative to the pes was evaluated in a straight tibial caudocranial if tibial torsion correction was performed.[30]

Follow-up radiographs were scheduled at 4 weeks after surgery and then monthly thereafter until radiographic bone healing was achieved if corrective osteotomies were performed.[33]

Radiographic signs such as implant dislodgement, peri-implant radiolucency, osteolysis, periosteal reaction, and soft tissue radiopacity were evaluated to assess the presence of implant loosening or infection.

Clinical Outcomes

Every dog was assessed preoperatively, before discharge, and during the clinical reassessments scheduled at suture removal and at 1 and 2 months postoperatively. During each clinical reassessment, lameness evaluation was first performed followed by physical palpation to detect the presence of fluid discharge, soft tissue swelling, pain elicited during stifle range of motion, and patellar position. Patellar position was assessed in both the standing position and lateral recumbency during static and dynamic conditions. Postoperative clinical outcomes were classified as full function, acceptable function, and unacceptable function depending on the grade of postoperative lameness, patellar position, and complications observed.[23]

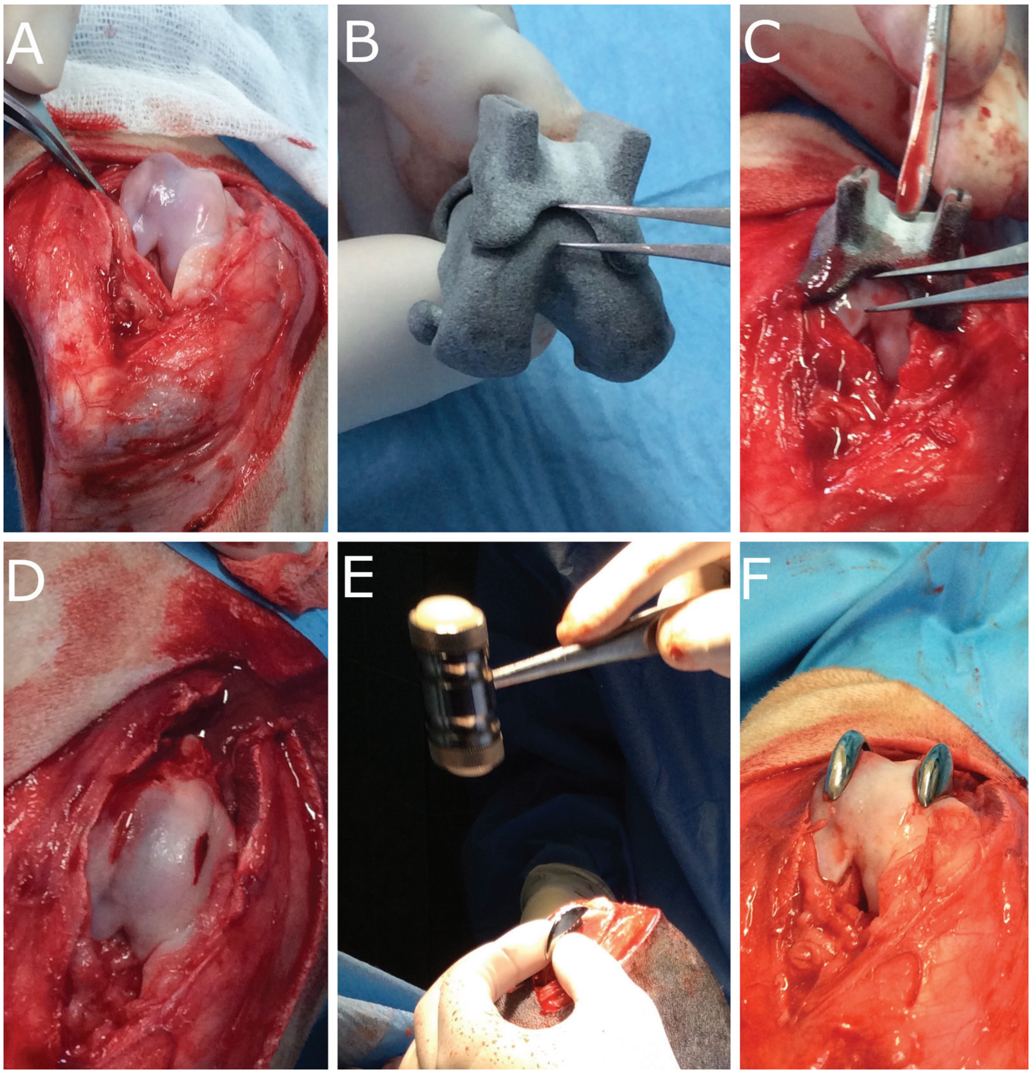

Fig. 5 Intraoperative images showing a shallow femoral trochlear groove (**A**), the assessment of the distance from the cutting guide to the femoral intercondylar notch at each point of each trochlear ridge (**B**), positioning of the cutting guide on the femoral trochlear groove (**C**), presence of two osteotomies on the femoral trochlear ridges (**D**), TRP impaction via Teflon hammer (**E**), and TRP final positioning (**F**). TRP, trochlear ridge prosthesis.

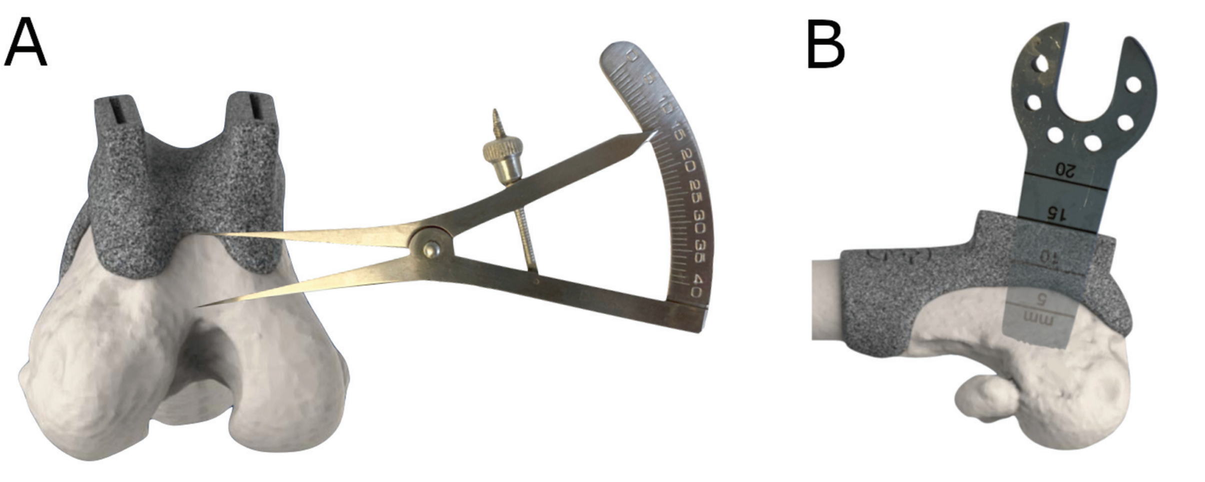

Fig. 6 Image (**A**) shows the technique to evaluate proper positioning of the cutting guide by measuring the distance from the guide to the proximal aspect of the femoral intercondylar notch on the femoral anatomical replica. Image (**B**) shows the method for assessing the depth of the osteotomy using a graduated sagittal saw blade.

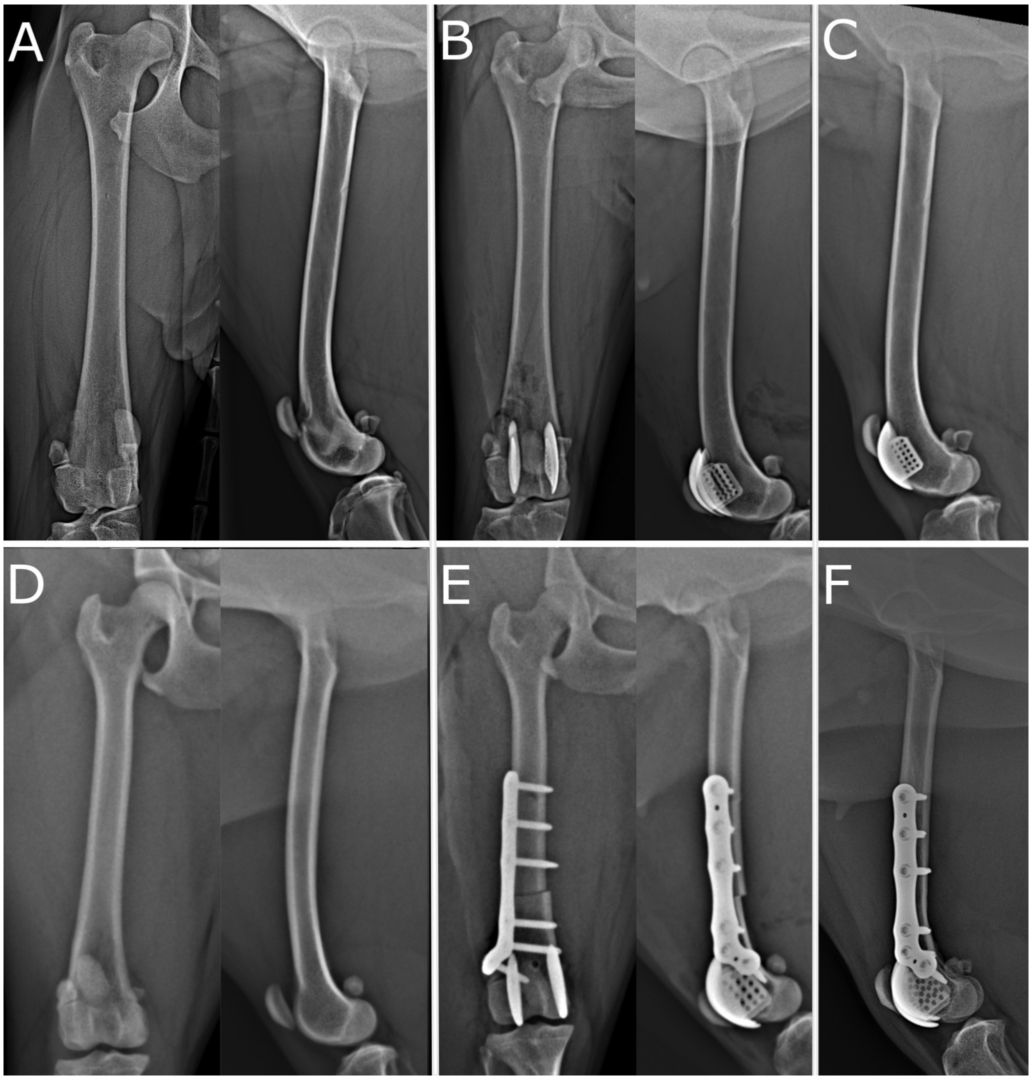

Fig. 7 Pre-, immediate postoperative orthogonal radiographic projections (**A, B**) and postoperative mediolateral radiographic view (2 months postoperatively, **C**) of one case (case 41) treated exclusively using TRP. Pre-, immediate postoperative orthogonal radiographic projections (**D, E**) and postoperative mediolateral radiographic view (10 months postoperatively, **F**) of a case treated using a TRP with distal femoral osteotomy. TRP, trochlear ridge prosthesis.

Results

Study Population

Forty-eight dogs met the inclusion criteria. The signalment, body weight, direction, and degree of patellar luxation are summarized in ►**Appendix Table 1** (available in the online version). Eighteen dogs were males, and 30 were females. The age ranged from 9 to 108 months (mean: 36.6 months; standard deviation [SD]: ± 26.5). Body weight ranged from 1.3 to 23 kg (mean: 5.6 kg; SD: ± 4.1). The most represented breeds were mixed breed ($n = 15$) and toy Poodle ($n = 8$).

Preoperative Clinical Findings and Measurements

Sixty stifles received TRP. Medial patellar luxation was found in 55 stifles: grade 2 ($n = 4$), grade 3 ($n = 43$), and grade 4 ($n = 8$). Lateral patellar luxation was diagnosed in the remaining 5 stifles: grade 3 ($n = 1$) and grade 4 ($n = 4$) (►**Appendix Table 1** [available in the online version]). All 48 dogs were lame before surgery (score range: 3–5). In detail, 5/60 cases had a score of 3, 47/60 cases had a score of 4, and 8/60 cases had a score of 5 for preoperative lameness (►**Appendix Table 1** [available in the online version]). Among the 60 stifles treated, 3/60 did not show any hindlimb deformities, 18/60 had tibial torsion, 4/60 femoral varus, 8/60 femoral torsion, 3/60 tibial torsion with femoral varus, 14/60 tibial torsion with femoral torsion, 1/60 femoral varus with femoral torsion, and 9/60 tibial torsion with both femoral varus and torsion.

Surgery

Twenty-four out of 60 stifles were treated only with TRP. In 36/60 stifles, other surgical techniques were performed in addition to TRP (►**Appendix Table 2** [available in the online version]). Within the group where TRP was the only surgical procedure, no hindlimb deformities ($n = 1$), femoral deformities ($n = 6$), tibial deformities ($n = 12$), or concurrent femoral and tibial deformities ($n = 5$) were observed.

TRP was applied with tibial tuberosity transposition (TTT; $n = 13$), proximal tibial osteotomy (PTO; $n = 1$), a modified tibial plateau leveling osteotomy (m-TPLO) ($n = 1$), distal femoral osteotomy (DFO; $n = 12$), DFO and TTT ($n = 2$), and DFO with PTO ($n = 7$). A total of 30 corrective osteotomies were performed: DFO ($n = 21$) and PTO ($n = 9$). Retinaculum imbrication was performed in 52 stifles (lateral, $n = 47$: medial, $n = 5$), while retinaculum release was performed in 33 stifles (lateral, $n = 5$: medial, $n = 27$).

Postoperative Radiographic and Clinical Outcome

The radiographic follow-up was classified as perioperative ($n = 44$ stifles), short-term ($n = 8$ stifles), mid-term ($n = 4$ stifles), and long-term radiographic ($n = 4$ stifles) follow-up (►**Appendix Table 2** [available in the online version]). The radiographic follow-up ranged from 2 to 23 months (mean: 3.8 months; SD: ± 4). At the 2-month radiographic reassessment, TRP was found in all 60 stifles in the proper position with no radiographic signs of implant loosening or implant infection. The patella was found in a central position in 59/60 stifles. Soft tissue periarticular swelling was detected in 7/60 stifles. Whenever a corrective osteotomy was performed ($n = 30$), the radiographic bone union ranged from 1.5 to 3.3 months (mean: 2.1 months; SD: ± 0.3). All the femoral closing wedge ostectomies ($n = 21$) restored the physiological frontal femoral alignment (►**Appendix Table 3** [available in the online version]). The radiographic axial tibial alignment was deemed physiological in 9/9 PTO (►**Appendix Table 3** [available in the online version]).

The postoperative clinical outcomes included full function in 57/60 of treated stifles, acceptable function in 2/60, and unacceptable function in 1/60 (►**Appendix Table 2** [available in the online version]). At the 2-month follow-up, all dogs improved with lameness scores ranging from 0 to 3. Specifically, 57/60 stifles did not show residual lameness, whereas 3 dogs showed persistent lameness but with a lower score than noted before surgery. In two dogs, the lameness score improved from grade 4 to grade 1, but the physical examination of the stifle elicited moderate pain.

Complications

Overall, we observed complications in 3/60 cases, including 2 minor complications and 1 one major complications.

The two minor complications included the presence of grade 1 lameness lasting until 4 months after surgery in one case and until 2 months in another case. The supposed cause was the presence of periarticular fibrosis and soft tissue tension around the TRP and patella.

The major complication was medial patellar luxation recurrence 4 months after surgery. The preoperative evaluation showed abnormal external tibial and femoral torsion. The dog received a TRP in combination with TTT, whereas the femoral deformities were not corrected.

Discussion

This study describes a custom-made implant designed to augment the femoral trochlear ridges and reports the clinical outcomes and complication rate after applying TRP in 48 dogs (60 canine stifles) affected by patellar luxation.

In this study, TRP allowed for the correction of patellar luxation in 59/60 dogs, improving also the preoperative lameness in almost all cases, with 45/48 of dogs returning to normal function. A low complication rate was observed.

The TRP design and application technique offer some advantages compared to trochleoplasty.[6,8,34] The goal of trochleoplasty is to create a wide and deep osteochondral graft so that at least 40 to 50% of the patella is held within the femoral trochlear groove.[35] To achieve this purpose, at least two osteotomies are performed in the femoral trochlear groove cartilage. With TRP, the femoral trochlear groove cartilage is spared because the height of the femoral trochlear ridges is augmented instead of deepening the groove. Similar to trochleoplasty, two intraarticular osteotomies are required but they are performed at the top of the femoral trochlear ridges, where no weight-bearing is expected. It has been reported that techniques that better preserve cartilage result in faster return to function and reduced osteoarthritis progression.[6,9,36]

Although trochleoplasty is a popular surgical technique in human[37–40] and veterinary orthopaedics,[8,14] it may be associated with complications that include long-term osteoarthritis development,[12,22] migration of the osteochondral graft,[13] and fracture of the femoral trochlear ridges.[12] Trochleoplasty is a free-hand procedure, while the osteotomies for TRP application are performed with a cutting guide which ensures an accurate execution of the osteotomies in the ridge area where the most bone purchase is present.

To mention TRP pitfalls, additional diagnostics (CT), manufacturing time (usually 1 week), and superior costs represent the main disadvantages compared to trochleoplasty. Implant-related complications are also potential limitations. However, in this study, neither implant loosening nor infections were observed.

The TRP was applied either in combination with other surgical techniques or as the main surgical procedure to treat patellar luxation. Although we cannot draw definitive conclusions on TRP efficacy, we can extrapolate from our data that TRP contributed to restoring patellar luxation in the short term at the cost of minimal complications.

The TRP was successfully applied with DFO, PTO, and TTT. The reason for combining TRP with corrective osteotomies or traditional techniques was mainly ascribable to the presence of a hindlimb deformity. Among the cases where TRP was applied with other techniques, only one case failed due to recurrence of medial patellar luxation. This failure was attributed to the lack of correction of the femoral deformity.

In patellar luxation cases, it is occasionally possible to encounter hindlimb deformities that are deemed mildly abnormal. Under these circumstances, it is possible to treat patellar luxation without addressing these deformities but using traditional techniques (i.e., TTT or trochleoplasty). The TRP was applied in 24 stifles as the only surgical procedure.

Concerning the main features of TRP, although their profile is generally the same, slight modifications ensure proper implant fit for each dog. The TRP prototyping is designed to minimize the area of interface between the extraosseous component of the implant and the trochlear ridge. As a result, the presence of sharp or bulky components is reduced, thus ensuring better prosthesis fitting. In contrast, providing the proper fit for each dog may be difficult to achieve using implants with standardized dimensions, potentially leading to an under- or oversized implant that may eventually cause recurrent patellar luxation or patellar impingement.

The use of a titanium rectangular perforated plate as an intraosseous-fixation method allows for an optimal press-fit impaction and promotes osteointegration. Titanium was chosen given its reported biocompatibility and osteointegration properties.[22,41]

The above-mentioned aspects are benefits of TRP compared to the Ridgestop**.** The titanium intraosseous plate is less cumbersome than the use of screws. Additionally, screw insertion can be challenging particularly in a small and curved articular surface and screws may be affected by loosening. In the Ridgestop case series, 1/4 cases had screw loosening. In this study, no implant loosening was observed in 60 cases.

This study has some limitations. The main limitation was its retrospective nature given that some of the surgery records and postoperative outcome assessment may not be complete. The follow-up is relatively short-term and therefore we cannot comment neither on potential development of osteoarthritis after TRP implantation nor cartilage injury. Additionally, postoperative objective measurement outcomes, such as goniometry and force plate analysis, were not performed.

Second, apart from the postoperative radiographic follow-up, we did not perform additional diagnostics to assess the postoperative development of osteoarthritis. It would be possible that chondral lesions on the patellar abaxial and articular surfaces may have increased the odds for postoperative osteoarthritis development.

In conclusion, TRP represents a surgical option to improve patellar accommodation within the femoral trochlear groove in dogs affected by patellar luxation. Surgical indications include dogs affected by patellar luxation associated with trochlear dysplasia, hypoplasia of the femoral trochlear ridges, with no or minimal cartilage lesions of the femoral trochlear groove.

The restoration of physiologic patellar tracking with the benefit of nominal damage to the femoral trochlear cartilage is the main advantage of TRP. Additionally, the TRP was not developed as an end-stage procedure and therefore provides the opportunity for other surgeries should patellar maltracking recur.

Note

Dr. Tommaso Nicetto holds the patent for TRP (nr. 102019000024472).

Authors' Contribution

T.N.: invented TRP, concepted and designed the study, collected data, reviewed the medical record, and drafted the manuscript. F.L.: participated in the design of the study, reviewed the medical records, collected data, analyzed and interpreted the data, and drafted the manuscript.

Conflict of Interest

None declared.

Acknowledgment

The authors would like to thank Andrea Sandi and 3Dfast s.r.l. (Padova, Italy) for technical support in design and production.

References

1 Alam MR, Lee JI, Kang HS, et al. Frequency and distribution of patellar luxation in dogs. 134 cases (2000 to 2005). Vet Comp Orthop Traumatol 2007;20(01):59–64
2 Bound N, Zakai D, Butterworth SJ, Pead M. The prevalence of canine patellar luxation in three centres. Clinical features and radiographic evidence of limb deviation. Vet Comp Orthop Traumatol 2009;22(01):32–37
3 Perry KL, Déjardin LM. Canine medial patellar luxation. J Small Anim Pract 2021;62(05):315–335
4 Dejour H, Walch G, Neyret P, Adeleine P. Dysplasia of the femoral trochlea [in French]. Rev Chir Orthop Repar Appar Mot 1990;76 (01):45–54
5 Johnson AL, Probst CW, Decamp CE, et al. Comparison of trochlear block recession and trochlear wedge recession for canine patellar luxation using a cadaver model. Vet Surg 2001;30(02):140–150
6 Katayama M, Ogaya H, Shunsuke S, Uzuka Y. Kite shield-shaped wedge recession for treatment of medial patellar luxation in seven small-breed dogs. Vet Surg 2016;45(01):66–70
7 Nagahiro Y, Murakami S, Kamijo K, et al. Segmental femoral ostectomy for the reconstruction of femoropatellar joint in dogs with grade IV medial patellar luxation. Vet Comp Orthop Traumatol 2020;33(04):287–293
8 Slocum B, Slocum TD. Trochlear wedge recession for medial patellar luxation. An update. Vet Clin North Am Small Anim Pract 1993;23(04):869–875
9 Cashmore RG, Havlicek M, Perkins NR, et al. Major complications and risk factors associated with surgical correction of congenital medial patellar luxation in 124 dogs. Vet Comp Orthop Traumatol 2014;27(04):263–270
10 Wangdee C, Hazewinkel HA, Temwichitr J, Theyse LF. Extended proximal trochleoplasty for the correction of bidirectional patellar luxation in seven Pomeranian dogs. J Small Anim Pract 2015; 56(02):130–133
11 van der Zee JH. Lesions in canine stifle joints due to trochleoplasties as treatment for medial patellar luxation. J S Afr Vet Assoc 2015;86(01):1245
12 Chase D, Farrell M. Fracture of the lateral trochlear ridge after surgical stabilisation of medial patellar luxation. Vet Comp Orthop Traumatol 2010;23(03):203–208
13 Ellis LF, House AK. Trochlear block recession sulcoplasty migration in a dog. J Small Anim Pract 2021;62(09):823
14 Rossanese M, German AJ, Comerford E, Pettitt R, Tomlinson A, de Vicente F. Complications following surgical correction of medial patellar luxation in small-to-medium-size dogs. Vet Comp Orthop Traumatol 2019;32(04):332–340
15 Moore JA, Banks WJ, Blass CE. Repair of full-thickness defects in the femoral trochlea of dogs after trochlear arthroplasty. Am J Vet Res 1989;50(08):1406–1413
16 Dokic Z, Lorinson D, Weigel JP, Vezzoni A. Patellar groove replacement in patellar luxation with severe femoro-patellar osteoarthritis. Vet Comp Orthop Traumatol 2015;28(02):124–130
17 Kim Y, Park Y, Park J, Jeong SM, Lee H. Bilateral patellar groove replacement in a dog with iatrogenic trochlear groove damage. J Vet Clin 2016;33:295–299

18 Jaworski J, Krukowski M, Gosling M, Burton N. Patellar groove replacement in a cat. VCOT Open. 2022;5:e71–e77
19 Mills J, Hargittai T. Treatment of feline patellar luxation with polyethylene sulcal ridge prostheses. J Small Anim Pract 2020;61(11):704–709
20 Nicetto TLF. Early experience with trochlear ridge prosthesis for reshaping the femoral trochlear ridges in dogs with patellar luxation. In:Proceedings of the European Society of Veterinary Orthopedics and Traumatology,. Nice, France.2022
21 Nicetto T, Longo F, Contiero B, Isola M, Petazzoni M. Computed tomographic localization of the deepest portion of the femoral trochlear groove in healthy dogs. Vet Surg 2020;49(06): 1246–1254
22 Trindade R, Albrektsson T, Galli S, Prgomet Z, Tengvall P, Wennerberg A. Osseointegration and foreign body reaction: titanium implants activate the immune system and suppress bone resorption during the first 4 weeks after implantation. Clin Implant Dent Relat Res 2018;20(01):82–91
23 Cook JL, Evans R, Conzemius MG, et al. Proposed definitions and criteria for reporting time frame, outcome, and complications for clinical orthopedic studies in veterinary medicine. Vet Surg 2010; 39(08):905–908
24 Putnam RW. Patellar Luxation in the Dog. Guelph: University of Guelph,; 1968
25 Tomlinson J, Fox D, Cook JL, Keller GG. Measurement of femoral angles in four dog breeds. Vet Surg 2007;36(06):593–598
26 Dudley RM, Kowaleski MP, Drost WT, Dyce J. Radiographic and computed tomographic determination of femoral varus and torsion in the dog. Vet Radiol Ultrasound 2006;47(06):546–552
27 Longo F, Savio G, Contiero B, et al. Accuracy of an automated three-dimensional technique for the computation of femoral angles in dogs. Vet Rec 2019;185(14):443
28 Longo F, Nicetto T, Pozzi A, Contiero B, Isola M. A three-dimensional computed tomographic volume rendering methodology to measure the tibial torsion angle in dogs. Vet Surg 2021;50(02): 353–364
29 Apelt D, Kowaleski MP, Dyce J. Comparison of computed tomographic and standard radiographic determination of tibial torsion in the dog. Vet Surg 2005;34(05):457–462
30 Slocum B, Slocum T. Tibial Plateau Leveling Osteotomy Certification Course. Eugene, OR: Slocum-Enterprises Inc.; 2000
31 Petazzoni M, Jaeger GH. Atlas of Clinical Goniometry and Radiographic Measurements of the Canine Pelvic Limb. Duluth: Merail; 2008
32 DeCamp CE. Brinker, Piermattei, and Flo's Handbook of Small Animal Orthopedics and Fracture Repair. Philadelphia, PA: Saunders; 2016
33 Guiot LP, Déjardin LM. Prospective evaluation of minimally invasive plate osteosynthesis in 36 nonarticular tibial fractures in dogs and cats. Vet Surg 2011;40(02):171–182
34 Flo GL. Surgical Correction of a Deficient Trochlear Groove in Dogs with Severe Congenital Patellar Luxations Utilizing a Cartilage Flap and Subchondral Grooving [MS Thesis]. Michigan: Michigan State University, Department of Veterinary Surgery and Medicine; 1969
35 Hansen JS, Lindeblad K, Buelund L, Miles J. Predicting the need for trochleoplasty in canine patellar luxation using pre- and intra-operative assessments of trochlear depth. Vet Comp Orthop Traumatol 2017;30(02):131–136
36 Boone E. Trochlear recession wedge technique for patellar luxation: an experimental study. J Am Anim Hosp Assoc 1983;19(05): 735–742
37 Donell ST, Joseph G, Hing CB, Marshall TJ. Modified Dejour trochleoplasty for severe dysplasia: operative technique and early clinical results. Knee 2006;13(04):266–273
38 Utting MR, Mulford JS, Eldridge JD. A prospective evaluation of trochleoplasty for the treatment of patellofemoral dislocation and instability. J Bone Joint Surg Br 2008;90(02):180–185
39 Davies MR, Allahabadi S, Diab TE, et al. Sulcus-deepening trochleoplasty as an isolated or combined treatment strategy for patellar instability and trochlear dysplasia: a systematic review. Arthrosc Sports Med Rehabil 2020;2(05):e661–e669
40 Elias JJ, Rezvanifar SC, Koh JL. Groove-deepening trochleoplasty reduces lateral patellar maltracking and increases patellofemoral contact pressures: dynamic simulation. J Orthop Res 2022;40(07):1529–1537
41 Trevisan F, Calignano F, Aversa A, et al. Additive manufacturing of titanium alloys in the biomedical field: processes, properties and applications. J Appl Biomater Funct Mater 2018;16(02):57–67

