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Feasibility and cartilage injury of an all-inside arthroscopic meniscal repair application in a canine cadaveric study

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ABSTRACT

Meniscal injury is the most common comorbidity in canine stifles with cranial cruciate ligament (CCL) pathology. Arthroscopic repair for acute tears can be technically challenging and is rarely described. This study evaluates the feasibility of using an all-inside arthroscopic meniscal repair device, Arthrex Meniscal Cinch II™ (MCII) in canine cadaveric stifles and the associated risks of iatrogenic vascular injury (IVI) and cartilage injury (ICI). 20 healthy paired canine cadaveric stifles (25 – 45 kg BW) were divided randomly into two groups of 10. Both groups received transection of the CCL via mini arthrotomy, joint distraction and diagnostic arthroscopy with meniscal probing. No further procedures were performed in the control group whereas the implant group underwent placement of the MCII-implants in the caudal horn of the medial meniscus. Angiography of the femoral artery was performed for each limb before and after operation and vascular trauma was assessed on radiographs. After disarticulation, the cartilage was stained via Indian ink assay and underwent blinded scoring for ICI. Implants were evaluated for desired position. Correct position of the MCII-implants was achieved in all stifles. No IVI was detected. Implant placement created more ICI on the medial femoral condyle (1.33 mm^2) than arthroscopy alone (0.15 mm^2) ($p = 0.03$). Implant associated complications occurred in 30 %. Arthroscopic use of MCII is feasible and carries minimal risk for vascular damage. Despite joint distraction, implant placement using the MCII is associated with significant cartilage damage. Although technically challenging, all-inside meniscal repair appears to carry limited risk in canine patients over 25 kg bodyweight.

Introduction

Meniscal injury is one of the most common findings in the canine stifle joint concurrent with cranial cruciate ligament tear (CCLT) (Smith et al., 2002). Untreated meniscal damage at initial CCL surgery can cause persistent lameness and the need for an additional intervention (Case et al., 2008; Metelman et al., 1995).

The medial meniscus is significantly more often affected than the lateral one, due to its decreased mobility and better fixation to the medial collateral ligament and joint capsule (Bennett and May, 1991; Case et al., 2008; Flo, 1993; Park et al., 2018; Slocum and Slocum, 1993). It is well recognized, that medial meniscal release and meniscectomy have detrimental effects on intra-articular load transmission (Pozzi et al., 2008) and joint stability (Jensen et al., 2020; Pozzi et al., 2006). Both are reported to have poor long-term outcome with progression of degenerative joint disease (DJD) (Cox et al., 1975; Innes et al., 2000), despite acceptable short to midterm outcome in combination with joint stabilization after CCLT (Case et al., 2008; Saban et al., 2023; Thieman et al., 2006).

Meniscal repair has been shown to restore normal stifle contact mechanics in an ex-vivo study with canine stifles with acute iatrogenic bucket handle tear of the caudal horn of the medial meniscus (Thieman et al., 2010). In dogs, inside-outside and outside-inside techniques have been described as successful in cadavers and in clinical patients (Cook and Fox, 2007; Rocheleau et al., 2024; Rovesti et al., 2018; Thieman et al., 2010).

In humans, multiple different arthroscopically assisted meniscal repair techniques have been described (Cannon, 1996; Cannon and Morgan, 1994; Morgan and Casscells, 1986; Rodeo, 2000; Scott et al., 1986; Warren, 1985). Over the last decades, specifically designed

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devices for meniscal repair have gained more popularity. They avoid accessory incisions and allow for an all-inside arthroscopic meniscal repair, decreasing the risk of neurovascular injury and dramatically reducing surgical time (Barber and McGarry, 2007; Jenkins et al., 2019; Sgaglione et al., 2003).

Although these devices were designed for meniscal repair in human patients, they could be applied in canine patients as well. Nevertheless, a successful application and risk assessment in the canine stifle has not been described so far.

The aim of this study is to evaluate iatrogenic vascular injury (IVI) and iatrogenic cartilage injury (ICI) after using an all-inside arthroscopic meniscal repair device (Meniscal Cinch II™, MCII) (Arthrex®, Naples Florida, USA) in the caudal horn of the medial meniscus in canine cadaveric stifles and to describe the technique, limitations and possible complications of this procedure. The MCII is an all-inside meniscal repair implant delivery system. It works through deployment of two low-profile (1.1 mm thick) PEEK-buttons (poly-ether-ether-ketone), that are connected with a 2–0 FiberWire® (Arthrex®, Naples Florida, USA) and a pre-tied low-profile knot.Our hypotheses were, that desired placement of the MCII-implants in the caudal horn of the medial meniscus is feasible, causes no IVI and the equal amount of ICI to the medial femoral condyle in comparison to the control group.

Materials and methods

Cadaver preparation

For this ex vivo cadaveric study, paired hindlimbs, disarticulated in the hip joint, from 10 canine cadavers (n = 20) with a bodyweight over 25 kg were collected. The animals died or were euthanized due to reasons unrelated to the study and without history of stifle disease. The owners gave their written consent for the cadavers to be used for scientific purpose.

Orthogonal stifle radiographs were performed to rule out severe osteoarthritis and other pathologies (Fig. 1A + B). The legs were clipped, kept frozen at −20°C and were thawed at room temperature 24–48 h prior to surgery. The femoral artery was catheterized just distal to the descending genicular artery with an 18 G venous catheter (Vasofix®, B. Braun Austria GmbH, Maria Enzersdorf, Austria) and angiography with barium-sulfate (Bariumsulfat, Caesar & Loretz GmbH, Hilden, Germany) in a liquid mix with saline solution (1: 1) was performed for each limb before and after the procedure (Fig. 1C + D). Inclusion criteria were a bodyweight over 25 kg, no severe radiological signs for osteoarthritis or history of stifle disease. Exclusion criteria were arthroscopically visible meniscal- or full cartilage-defects, that were not interpreted as iatrogenic.

Pilot legs

Six paired stifles were used as pilot specimens to determine portal size, choice of portal for implant insertion and to practice application of the distractor and implant placement. Gross dissection was performed to assess meniscal enter- and exit-points of the MCII.

Procedure

The legs were fixed to the operating table with a vice at the level of the proximal femur. Skin was retracted with towel clamps and the femur was positioned at approximately 45° to the axis of the operating table. All procedures were performed by two board-certified specialists (DECVS and DSAS(Orth)), both with more than 10 years of stifle arthroscopy experience.

Complete CCL transection was performed in all stifles via a craniolateral mini arthrotomy. An extraarticular stifle distractor (Leizpig stifle distractor, Karl Storz Endoskope, Tuttlingen, Germany) was placed as described previously (Winkels et al., 2016) with 3.0 mm non threaded pins and the joint was distracted under arthroscopic control. An additional medial parapatellar camera port was placed and standard arthroscopy with a 30°, 2.7 mm arthroscope (Arthrex® Inc., Naples Florida, USA) from the craniolateral portal with probing of the menisci from the craniomedial portal was performed in all 20 limbs.

The stifles of each dog were randomly assigned to one of two groups. For the control group (C-group) the procedure ended after probing.

The implant group (MCII-group) underwent placement of the MCII-implants through the craniolateral or craniomedial portal into the caudal horn of the medial meniscus (Video 1). The MCII allows deployment of two low-profile (1.1 mm thick) PEEK-buttons (poly-ether-ether-ketone), that are connected with a 2–0 FiberWire® (Arthrex®, Naples Florida, USA) and a pre-tied low-profile knot.

Full arthroscopic observation of the medial meniscus was achieved. The Meniscal Cinch II™ was inserted into the joint without the adjustable depth-stop recommended by the manufacturer under arthroscopic guidance. Button No.1 was deployed first in the abaxial position (Fig. 2A). Button No.2 was preloaded (Fig. 2B) and deployed in a second axial position. The MCII needle was removed from the joint and the Knot Pusher / Suture Cutter (Arthrex®, Naples Florida, USA) was used to tighten the 2–0 Fiber-Wire® suture-knot (Fig. 2C) and to cut the remaining suture, completing the implantation (Fig. 2D).

Intraoperative findings and complications were documented. Total surgical time (T-Total) for both groups and implantation time for the MCII-group (T-Cinch) was recorded.

Iatrogenic vascular injury (IVI) - scoring

Postoperative orthogonal radiographs were repeated in the same fashion as before the operation (Fig. 1 E + F). One investigator, not

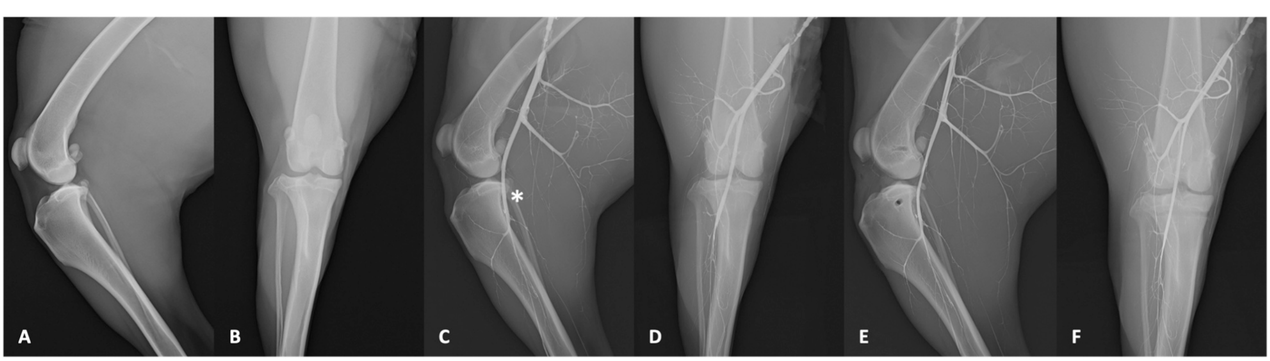
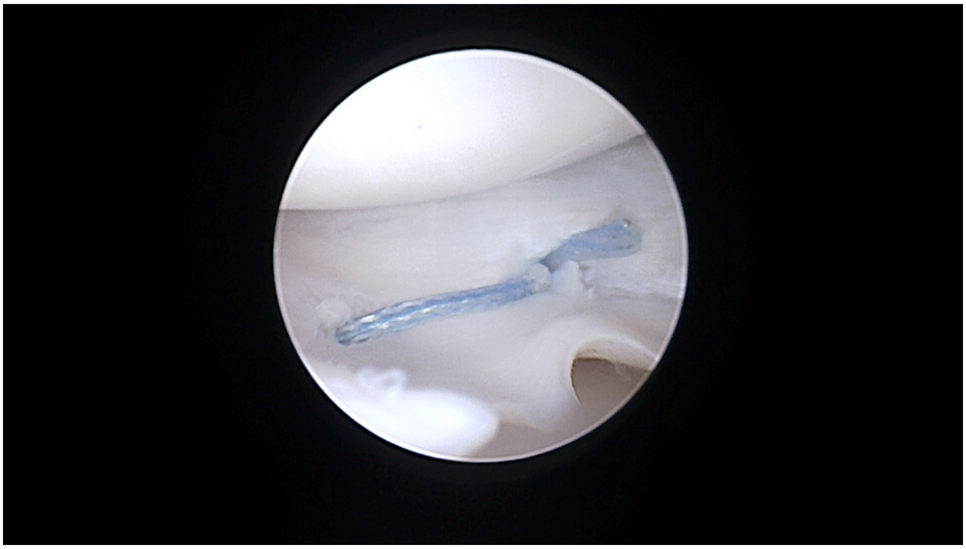


Fig. 1. Mediolateral and craniocaudal radiographs of leg No.6 (MCII-group) pre contrast (A, B), post contrast angiography of the cranial tibial artery preoperatively (Asterix, C, D) and postoperatively with pin holes of the stifle distractor (E, F). Integrity of the cranial tibial artery can be appreciated in all contrast radiographs.



Video 1. Shows the application process of the Meniscal Cinch II™ into the caudal horn of the medial meniscal in the right stifle of cadaver No. 8 through the medial parapatellar portal with arthroscopic view from the lateral parapatellar portal. The first button is deployed in the abaxial position, the second in the axial position. The Knot Pusher / Suture Cutter is used to tighten the knot along the guiding suture towards the first button. After implantation is complete, tightness of the implant and possible perforation on the ventral meniscal surface is controlled with a meniscal probe.A video clip is available online. Supplementary material related to this article can be found online at doi:10.1016/j.tvjl.2025.106339.

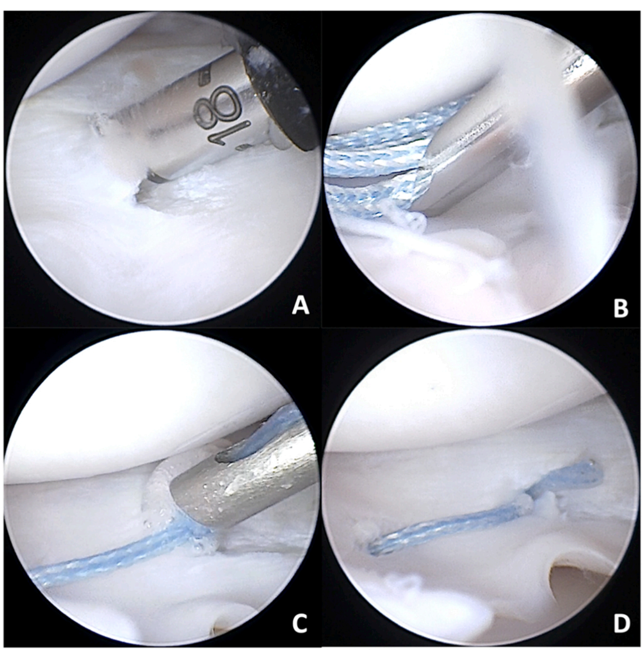


Fig. 2. Pictures of the arthroscopic implantation process and MCII-Needle insertion in stifle No.6. first into the abaxial position (A), followed by insertion into the second axial position (B). The Knot Pusher / Suture Cutter is used to tighten the knot along the guiding suture and is moved towards the first implant (C). Picture of the completed implantation of the MCII (D).

blinded to the groups, evaluated leakage from periarticular arteries and rated either as present or absent.

Implant-position-evaluation

The stifles were dissected without damaging the intraarticular structures and implant position was assessed. Firstly, the position of the MCII entry-points was graded as either in position (both in the caudal horn of the meniscus) or out of position. The caudal horn of the medial meniscus was defined as the part caudal to the cranial edge of the medial collateral ligament (Fig. 3). Secondly, the position of the buttons in regard to the horizontal plane of the meniscus were graded as either dorsal, central or ventral.

Iatrogenic cartilage injury (ICI) - scoring

The femora were dissected from the surrounding soft tissue and the femoral condyles were stained with Indian-Ink (Meachim and Fergie, 1975; Rogatko et al., 2018). High-definition photographs of both condyles were taken with the femur held in 45° angle to the lens axis with a ruler underneath, equidistant to the camera. The picture numbers were blinded to the examiner and uploaded into the GNU Image Manipulation Program (Gimp 2.10). Each picture was calibrated separately with the depicted ruler and every condyle was divided into four equal quadrants (Fig. 4). For each quadrant, number and area of ink-stained ICI was recorded. ICI was defined as well-defined, sharp-edged lesions, differentiating them from cobblestone-like ink uptake of osteoarthritic cartilage lesions (Cortés et al., 2019; Rogatko et al., 2018). For the medial condyle the total number of lesions (sum of lesions on all quadrants), the mean area per lesion and the total area of ICI (sum of all quadrants) were counted, regardless of quadrant.

Statistics

Statistical analysis was performed using IBM SPSS v29. Differences between groups in mean lesion area ICI and total area ICI of the medial condyle were analyzed using independent samples *t*-test, where the assumption of the normal distribution was tested before with the Shapiro-Wilk-test. Differences in total number of ICI on the medial condyle were analyzed using the nonparametric Mann-Whitney-test. For the correlations between total number of ICI, total area ICI and bodyweight Spearman's Correlation coefficient was used. For all analyses a p-value below 5 % ($p < 0.05$) was seen as significant.

Fig. 3. Stifle No.6 (MCII) after separation of femur and tibia reveals the implant in the caudal horn of the medial meniscus.

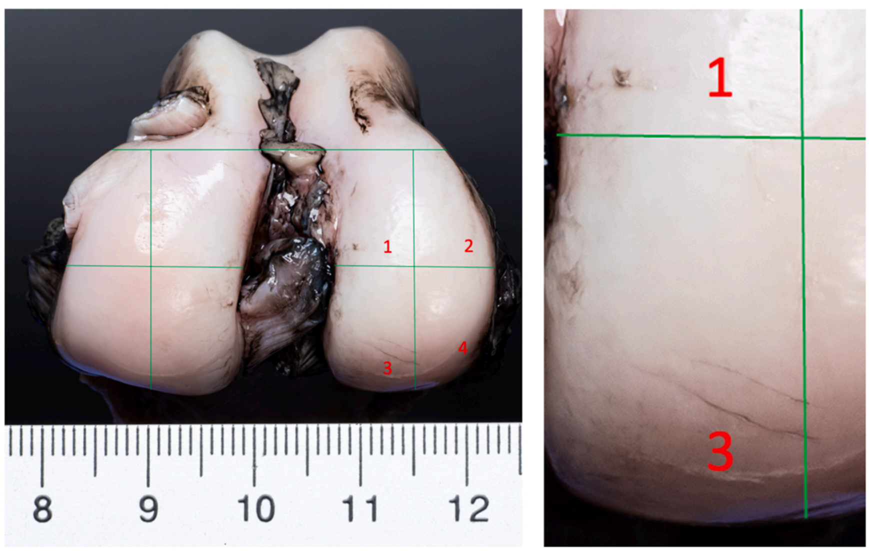


Fig. 4. Digital separation of the femoral condyles into 4 quadrants on stifle No.6 (MCII-group). End of the intercondylar notch forms the cranial point of the measured area. The length of the condyle is divided in half. This line is crossed halfway by a horizontal line, forming the 4 quadrants. For the medial femoral condyle, Quadrant 1 (Q1) starts cranially and axial, followed by Q2 abaxial and Q3 and Q4 caudally axial and abaxial respectively. In magnification on the right side two lesions in quadrant 3 are visible through indian ink staining.

Results

Twenty-two paired stifles met the radiologic inclusion criteria. One pair was excluded after arthroscopy due to a horizontal tear in the medial meniscus, partial CCL rupture and cartilage defects. The mean bodyweight was 35 kg (25.1 – 45.0), with six males and four females. Breeds included German Shepherd (2), Labrador Retriever (2), Ridgeback (1), Berger Blanc Swiss (1), Bernese Mountain Dog (1), Irish Wolfhound (1), Pitbull Terrier (1) and Staffordshire-Mix (1).

MCII-group had a mean surgical time of 19:57 min (SD±4:43) and C-group a mean time of 14:16 (SD±3:35 min). T-Cinch for MCII-group had a mean of 5:39 min (SD±3 min).

None of the angiography radiographs in either group showed signs of vascular leakage preoperatively or postoperatively.

All implants were placed into the caudal horn of the medial meniscus. The implant position was found ventrally in 12/20 and centered in 8/20 cases. Implant associated complication occurred in 3/10 operations. In stifle No.1, the suture was cut too long, leaving a remnant in the joint, although tightening was complete. In stifle No.13, the suture was cut accidentally prematurely, not finishing the tightening process. In stifle No.16, the caudal button entangled parts of the suture, leading to a visible doubled suture and additional premature cutting in the tightening process.

The total number of lesions ICI, mean area per lesion ICI and total area ICI on the medial condyle in both groups are displayed in Table 1. Total number of lesions ICI on the medial condyle was higher ($p = 0.09$) in the MCII-group 1.9 ± 1.52 than in the C-group 0.9 ± 0.99. Mean lesion ICI-area was higher ($p = 0.12$) in the MCII-group (1.01 mm^2 ± 1.35) in comparison with the C-group (0.2 mm^2 ± 0.29). There was a significant difference ($p = 0.03$) between total area ICI of the MCII-group (1.33 mm^2 ± 1.45) and the C-group (0.15 mm^2 ± 0.24) on the medial condyle.

No correlation was found between ICI-number, mean lesion ICI-area or total ICI-area on the medial condyle and the body weight in any group.

Table 1
Comparison between groups regarding iatrogenic cartilage injury (ICI) number and area on the medial femoral condyle.

	Group	Specimen (N)	Mean	SD
Total Lesion number (N)	MCII	10	1.90	1.52
	C	10	0.90	0.99
Mean Area per Lesion (mm^2)	MCII	9	1.01	1.35
	C	6	0.2	0.29
Total Area ICI (mm^2)	MCII	10	1.33	1.44
	C	10	0.15	0.24

MCII, Meniscal Cinch II Group; C, Control; SD; Standard deviation; ICI, iatrogenic cartilage damage

Discussion

This study is the first to describe arthroscopic use of an all-inside meniscal repair delivery system to place meniscal repair implants in canine cadavers. Feasibility of placement of the Meniscal Cinch II™-implants at the desired position of the meniscus was demonstrated in all cases and there was no evidence of IVI in any case, leading us to accept our first and second hypothesis. Out of the three measurements to quantify iatrogenic cartilage damage, total area of ICI on the medial condyle was significantly higher in the Implant-Group, which led us to reject our third hypothesis.

No evidence of iatrogenic vascular injury was noticed in any implantation. The angiography aims to rule out damage to greater arterial vessels near to the caudal joint capsule, like the popliteal artery. In humans, not vascular, but saphenous nerve damage has been described more commonly in the inside-out (Grant et al., 2012; Small, 1986), but also in all-inside techniques (Albrecht-Olsen et al., 1999; Grant et al., 2012; Steenbrugge et al., 2005). Avoidance of neurovascular damage is a reason to choose all-inside over inside-out techniques (Albrecht-Olsen et al., 1997, 1993; Morgan, 1991). In the dog, a small part of the cutaneous branch of the saphenous nerve follows the descending genicular artery to the deep surface of the medial stifle (Hermanson et al., 2020). Nerve damage in the area of deployment cannot be ruled out by this study, due to lack of staining method or visibility at dissection in this area. However, the caudomedial part of the joint only gets crossed superficially by the main saphenous nerve and artery as a cutaneous branch, making risk of iatrogenic damage unlikely.

Premature cutting and rupture of the suture resulted in 30 % complications in this study. This occurrence is likely due to surgical error in either the tightening process or by accidentally damaging the suture between button placements. The occurrence of the first can be prevented by advancing the Knot Pusher / Suture Cutter in line with the suture, avoiding friction and therefore damage to the suture (Goradia, 2013). We felt that accidental suture damage in correlation with too much suture slack in the arthroscopic field, possibly damaging or entangling the suture before or during the deployment of the second implant. The suture could be significantly damaged and, consequently, prematurely rupture in the tightening process. This challenge was addressed in the Meniscal Cinch™ by gently pulling on the suture on the back of the device, reducing impaired vision by suture slack (Goradia, 2013). In the second generation, namely Meniscal Cinch II™, this could be controlled only by incomplete advancement of trigger 2, which is not described in the user manual. A suture slot on the tip of the needle was specifically designed to allow protection of the suture and to avoid fraying during needle penetration in the second position. In our study, the relatively small canine stifle joint, even though distracted, posed a challenge to protecting the suture with this feature during the implantation process. The authors therefore recommend cadaveric wet labs to familiarize with the technique and the deployment mechanism.

The bodyweight did not correlate with any of the three ICI measurements. It is unclear if the MCII could be used in cadavers, weighing less than 25 kg, since this study only included patient over 25 kg. The MCII was designed for clinical use in human knee arthroscopy and could prove more challenging or even harmful in smaller canine patients. However, further studies are needed to investigate application in dogs falling below 25 kg bodyweight.

All three surgical complications that were encountered in this study could be salvaged, either by tightening and cutting the remaining suture with arthroscopic forceps or implant removal and placement of a new one. Rocheleau et al. recently mentioned a failed attempt of a meniscal repair with the MCII, that was successfully salvaged by performing conventional inside-outside repair (Rocheleau et al., 2024).

Of the three measurements to quantify iatrogenic cartilage damage, total area ICI on the medial condyle was significantly increased by the implantation process. Though not significant, number of lesions ICI and mean lesion area ICI was greater in the implant group as well. Given that, in one group, an implant was placed and in the other not, an even bigger difference in cartilage damage between groups could was expected. It has been reported that early all-inside repair devices struggled with cartilage damage (Ross et al., 2000). However, arthroscopy alone can cause significant cartilage lesions (Cortés et al., 2019; Rogatko et al., 2018). Cortés et al. reported a total area ICI of 5.2 mm^2 in the canine stifle joint when performing standard arthroscopy with commercial arthroscopic cannulas in comparison to silicon guarded cannulasin an ex vivo study. We measured 1.33 mm^2 of cartilage damage to the medial condyle in the MCII-group. Due to their differences in measurement method and study design, comparison to our study is difficult. Although ICI in our study does not even exceed 1.5 mm^2, the correlation of cartilage damage quantity to clinical effect or development of DJD is not well drawn in literature.

Despite the procedure being described as a single surgeon technique with placement of the MCII one handed (Jenkins et al., 2019), when first performed during this study, the technique was challenging. Therefore, we opted to have one surgeon holding the arthroscope while the other placed the MCII.

The depth-stop was left out in the study due to two reasons: It increases the diameter of the introducer, that is introduced into the joint, risking to increase ICI and subjectively limiting maneuverability and impairing precision. Additionally full length cannular engagement into the meniscus (>16 mm) ensured penetration and anchorage through the meniscal-capsular junction in all implants.

Twelve of the buttons exited on the ventral side of the meniscus and only eight laterally. To our knowledge, this variable has not been described so far. The MCII needle is pre-bent at 10° to facilitate easier insertion into the meniscal tissue. An increased steepness (>10°) when penetrating the meniscus could result in undesired ventral perforation. To avoid this, the angle at which the MCII enters the meniscus should be kept as low as possible. The canine meniscal height at the most abaxial point ranges from up to 8 mm in large breeds to approximately 4 mm in healthy beagles, narrowing axially to < 1 mm (Hermanson et al., 2020; Livet et al., 2022). The outer diameter of the MCII-needle measures 1.506 mm, deeming complete horizontal penetration challenging, depending on size and location of the meniscal tear and the meniscal thickness at that location. Additionally, proximal translation of the meniscus during implantation posed a challenge, resulting from stifle distraction and rising intra-articular fluid pressure, making it difficult to penetrate a floating target. Preemptive implant exit in horizontal repair could result in improper meniscal repair and implant failure in a clinical setting.

After distraction and exploration of the joint, mean time of MCII placement was 5:39 min (SD±3 min). In comparison, Rovesti et al. reported a mean meniscal suture time of 118 min (range: 90–140 min) in conventional inside-outside-inside fashion in 5 canine patients. Rocheleau et al. reported an inside-outside meniscal repair time of 5–30 min (Rocheleau et al., 2024). Clinical and cadaveric studies are hard to compare, and we lack a control group for traditional inside-outside technique in our study. However, fixation time with an all inside repair device is significantly reduced in human medicine by approximately 50 % with 30 min instead of 60 min (Albrecht-Olsen et al., 1999;

Grant et al., 2012).

Limitations of this study arise foremost from the use of cadavers. The freeze-thaw process may lead to weakened joint-supporting muscular-tendinous structures, resulting in a larger joint space when placed under distraction, in comparison with clinical patients. Use of healthy, non-fibrotic joints also permits wider distraction, possibly underestimating limited joint space and resultant ICI in regard to clinical application. However, the articular cartilage is influenced by the freeze-thaw as well, making it more susceptible to ICI, possibly overstating the occurrence/incidence of ICI in clinical patients (Peters et al., 2017).

Due to the lack of true meniscus lesions, statement about the accuracy of the repair method can only be made to a limited extent. The creation of meniscal defects preoperatively would have drastically increased the presence of ICI, making cartilage evaluation hard to interpret.

Conclusions

Use of an all-inside arthroscopic meniscal repair device (Meniscal Cinch II™, Arthrex®, Naples Florida, USA) in the cadaveric canine medial meniscus is feasible in short procedural time, without causing damage to major periarticular vessels. The technique may prove technically challenging and additional cartilage damage during the implantation process is to be expected.

This study provides a valuable insight into the technical aspects of the procedure and potential complications associated with MCII application in the canine stifle. Nevertheless, clinical studies are needed to further investigate benefits and outcome of all-inside arthroscopic repair in canine patients.

CRediT authorship contribution statement

Schnabl-Feichter Eva: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Tichy Alexander:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Data curation. **Pettitt Robert:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Michalik David:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of this paper. Eva Schnabl-Feichter and Rob Pettitt are consultants for Arthrex but have never received payments from the company for anything other than delivery of CPD.

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