Comparison of two cold compression therapy protocols after tibial plateau leveling osteotomy in dogs

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Keywords
Cranial cruciate ligament rupture, TPLO, postoperative pain management, postoperative rehabilitation

Summary
Objective: To evaluate two different protocols of cold compression therapy (CCT) for pain management and functional recovery in dogs undergoing tibial plateau leveling osteotomy (TPLO). **Material and methods:** A total of 27 adult dogs (n = 30 stifles; staged bilateral procedures: n = 3) undergoing routine TPLO were randomly allocated to three groups (n = 10/group). Dogs of group I received CCT once before and immediately after surgery. In dogs of group II CCT was performed postoperatively four times at 6-hour intervals. Dogs of the control group did not receive CCT. Circumference of the stifle joint and the following pain-related parameters were measured by a single blinded observer before surgery and 1, 10 and 42 days after surgery: stifle joint range of motion (ROM), subjective degree of lameness, and score of a modified Glasgow Pain Scale (GPS). **Results:** Both CCT groups showed significantly greater ROM and lower GPS scores 24 hours after surgery compared to the control group. Ten days after surgery there was a significantly lower degree of lameness in both CCT groups compared to the control group. Fourty-two days after surgery a significantly greater ROM was observed in both CCT groups compared to the control group. Group II also showed a significant improvement in the degree of lameness and GPS. There were no significant differences in any of the parameters between the two CCT groups at any time point. **Conclusion:** CCT applied preoperatively and immediately postoperatively showed similar short- and long-term beneficial results compared to a previously established protocol of applying CCT four times postoperatively. This protocol may be more suitable for practical use. **Clinical significance:** The reported data can be used to establish the new protocol of CCT in a clinical surrounding and to support postoperative rehabilitation of the canine patient.

Schlüsselwörter
Ruptur des vorderen Kreuzbands, TPLO, postoperatives Schmerzmanagement, postoperative Rehabilitation

Zusammenfassung
Ziel: Vergleich von zwei verschiedenen Protokollen der Kälte-Kompressionstherapie (KKT) im Hinblick auf Schmerzmanagement und postoperative Rehabilitation bei Hunden nach Tibial Plateau Leveling Osteotomy (TPLO). **Material und Methoden:** 27 adulte Hunde (30 Kniegelenke; drei etappenweise bilaterale Eingriffe), bei denen eine routinemäßige TPLO erfolgte, wurden zufällig drei Gruppen zugeteilt (n = 10/Gruppe): Hunde der Gruppe I erhielten die KKT einmalig vor und unmittelbar nach der TPLO, bei Patienten der Gruppe II kam sie postoperativ viermalig im Abstand von 6 Stunden zur Anwendung und bei Tieren der Kontrollgruppe unterblieb sie. Ein einzelner geblindeter Untersucher bestimmte vor der TPLO sowie 1, 10, und 42 Tage nach dem Eingriff den Umfang des Kniegelenks sowie folgende schmerzrelevante Parameter: Bewegungsumfang (range of motion, ROM) des Kniegelenks, Lahmheit (subjektive Beurteilung) und Schmerzgrad anhand einer modifizierten Glasgow Pain Scale (GPS). **Ergebnisse:** In Gruppe I und II ergaben sich 24 Stunden nach der TPLO im Vergleich zur Kontrollgruppe signifikant höhere ROM-Werte und signifikant niedrigere GPS-Werte. Der Lahmheitsgrad war 10 Tage nach der Operation in Gruppe I und II signifikant geringer als in der Kontrollgruppe. 42 Tage nach TPLO zeigten Gruppe I und II im Vergleich zu der Kontrollgruppe signifikant höhere ROM-Werte. Für Gruppe II ließ sich zu diesem Zeitpunkt zudem eine signifikante Verbesserung hinsichtlich Lahmheitsgrad und GPS feststellen. Für keinen Parameter und zu keinem Messzeitpunkt bestanden signifikante Unterschiede zwischen den Gruppen I und II. **Schlussfolgerung:** Die jeweils einmalige Anwendung der KKT prä- und postoperativ zeigt ähnlich vorteilhafte kurz- sowie langfristige Ergebnisse wie ein etabliertes Protokoll mit viermalig postoperativ angewandter KKT. Dieses neue Protokoll kann in einer klinischen Umgebung praxistauglicher sein. **Klinische Relevanz:** Die ermittelten Daten können genutzt werden, um das neue Protokoll der KKT in die klinische Umgebung einzuführen und die postoperative Rehabilitation der Patienten zu unterstützen.

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Introduction

Canine rehabilitation is one of the fastest growing branches in veterinary medicine and is frequently used to support the recovery after surgery for canine cruciate ligament disease (21). Cryotherapy is a rehabilitation method that is often utilized in people and animals to decrease pain and inflammation in the immediate postoperative period (15, 20). Cryotherapy in people following anterior cruciate ligament reconstruction has been shown to significantly reduce pain scores 48 hours after surgery (17). Rexing et al. (27) showed decreased soft tissue swelling 72 hours after stifle surgery in dogs by applying cold compression when compared to the use of a bandage alone. The beneficial effects of cryotherapy have been attributed to local vasoconstriction resulting in decreased blood flow, capillary permeability, edema formation, local hemorrhage and analgesia from decreased nerve conduction (9, 19, 20).

Cryotherapy in combination with intermittent dynamic pressure, a method referred to as cold compression therapy (CCT), has been shown to reduce stifle swelling, decrease postoperative pain and improve limb function after tibial plateau leveling osteotomy (TPLO) in dogs 24 hours after surgery (5). A recent meta-analysis showed that CCT is superior to cryotherapy alone in the acute rehabilitation stages in people undergoing knee surgery (30). These improvements are thought to be due to more intensive contact of the cooling aggregate with the skin (29) and the direct effects of compression (8, 25). CCT results in a reduced cellular metabolic rate of the affected tissue (23), vasoconstriction, decreased sensory and motor nerve conduction velocities (9, 18), provision of analgesia and reduced swelling (18), prevention of or reduction in trauma-induced edema, reduced blood flow and decreased muscle spasm by hypothermia (2, 9, 24). It has also been shown that hypothermia reduces pain by diminishing the concentration of inflammatory mediators such as tumor necrosis factor and nitric oxide (32).

Koyonos et al. (14) found that a single application of preoperative cryotherapy was associated with a lower pain score and decreased use of pain medication in the postoperative phase after anterior cruciate ligament reconstruction in humans when compared to no cryotherapy. To the authors' knowledge cryotherapy protocols utilizing preoperative treatment have not been assessed in the veterinary literature. Therefore, the objective of this study was to compare the effects of two different CCT protocols on range of motion (ROM), swelling, lameness and postoperative pain after TPLO in dogs. Our null hypothesis was that there is no difference in pain-related parameters in dogs receiving CCT preoperatively and once postoperatively compared to dogs receiving four sessions of postoperative CCT.

Materials and methods

Study population

Between June 2015 and April 2016 a total of 30 cranial cruciate ligament (CrCL)-deficient stifle joints from 27 dogs were enrolled from cases presenting to the Clinic for Small Animal Medicine, University of Veterinary Medicine Hannover Foundation, Hannover, Germany. All dogs underwent a full physical and orthopedic examination and the diagnosis of CrCL deficiency was based on a combination of the following features: hindlimb lameness, stifle joint effusion, positive cranial drawer sign or positive cranial tibial thrust and radiographic evidence of stifle joint effusion. Each stifle joint was also evaluated using magnetic resonance imaging[1] (MRI) before surgery to verify a partial or total rupture of the CrCL and rule out other pathologies. Dogs were excluded from the study if they had concurrent orthopedic diseases of the affected limb or showed highly anxious or aggressive behavior. A financial incentive was provided to the owners for participation in the study.

Anaesthesia, analgesia and perioperative care of animals

All dogs received a standardized anaesthesia/pain management protocol: Dogs were premedicated with acepromazine (0.05 mg/kg i.m., Vetranquil®, Ceva Tiergesundheit GmbH, Düsseldorf, Germany) and anaesthetized with diazepam (0.5 mg/kg i.v., Ziapam, Ecuphar GmbH, Greifswald, Germany), levomethadone (0.2 mg/kg i.v., L-Polamivet®, Intervet Deutschland GmbH, Unterschleißheim, Germany) and propofol (to effect, i.v., Narcofol®, CP-Pharma Handelsgesellschaft mbH, Burgdorf, Germany). Anaesthesia was maintained with isoflurane (Isofluran CP®, CP-Pharma Handelsgesellschaft mbH, Burgdorf, Germany) in oxygen using a vaporizer which was set at 1.5–3.0 %.

In all dogs preoperative epidural anaesthesia was performed with bupivacaine (0.5 mg/kg, Bupivacain-RPR-Actavis, Actavis GmbH, Salzburg, Austria) and morphine (0.1 mg/kg, Morphin HEXAL, Hexal AG, Holzkirchen, Germany). Dogs received amoxicillin/clavulanic acid (12.5 mg/kg, PO, q 12 h, Amoxiclav, CP-Pharma Handelsgesellschaft mbH, Burgdorf, Germany) for 10 days beginning 18 hours before surgery. After the TPLO-procedure all dogs received carprofen (4 mg/kg, p.o. q 24 hours, Rimadyl® Kautabletten, Zoetis Deutschland GmbH, Berlin, Germany) for 14 days with the first dose given 4 hours prior to surgery. No additional pain medication was administered and the owners were instructed to follow this protocol.

Tibial plateau leveling osteotomy

All surgeries were performed by the same surgeon (O.H.) and assistant (N.v.F.). If MRI had revealed damage to the medial menis-

[1] Philips Achieva 3T (TX) – DS MR System, Philips GmbH Market DACH, Health Systems, Hamburg, Germany

cus it was treated by a partial meniscectomy via a mini-arthrotomy without luxation of the patella. Otherwise no arthrotomy was performed. A standardized TPLO without the use of a jig was performed as described elsewhere (28). Briefly, soft tissue dissection including elevation of the pes anserinus was performed and a gauze soaked in saline (0.9 % NaCl) solution was placed caudoproximally to the tibia to protect the cranial tibial artery when performing the osteotomy. After surgery, the wound area was covered with an adhesive wound cover without any additional bandaging of the affected limb.

Cold compression therapy

A computer programme[2] was used to randomly assign study participants to one of three groups. All treatments were performed with the same CCT-device by one of the authors (N.v.F.). Dogs in group I received CCT directly before surgery and immediately after surgery for a duration of 20 minutes each while under general anaesthesia. In group II CCT was performed immediately after surgery under general anaesthesia, followed three times at 6-hour intervals for a duration of 20 minutes each. Dogs of the control group received sham CCT as outlined below.

The CCT system[3] consisted of a control unit with an integrated pump, an adjustable wrap designed to fit the stifle joint and a refreezable gel pack inlay with a hook-and-loop fastener. The gel pack was placed in a freezer until a temperature of 4 °C was achieved. This was verified by measuring multiple sections of the gel pack with an infrared thermometer[4]. An intermittent pressure of 50 mmHg was selected. The unit was set to inflate once every minute. The CCT system was attached to the dogs' stifle so that it was fitting properly to the skin by adjusting the straps' tightness. For dogs in the control group the adjustable wrap and gel pack inlay were applied for 20 minutes as performed for dogs in group I and II. However, the gel pack was used at room temperature and the pump device was not activated.

Measured parameters

The following pain-related parameters were measured 24 hours before and 1, 10, and 42 days after surgery. All measurements were performed by a single blinded observer (C. M.) experienced in veterinary rehabilitation. Blinding of the observer was accomplished by separating the observer from the recovery area when CCT treatments were performed. One day after surgery measurements of all parameters were taken approximately 6 hours after the last application of CCT to allow the dogs' stifle to revert to body temperature.

Range of motion (ROM) was measured with a goniometer[5] in lateral recumbent position as previously described (12). Briefly, the goniometer was placed on the lateral side of the particular limb with the center of the goniometer placed slightly above the centre of rotation of the stifle joint. The plastic wings of the goniometer were placed over the longitudinal axis of the tibia and femur. Extension was measured with the leg in standing position or mild extension. Flexion was measured with the hip in flexion without fixation of the tarsus. Extension and flexion were passively conducted several times as far as the dogs were maximally tolerating by showing no signs of pain or as long as there was no palpable resistance. The difference between the mean of the angles of extension and flexion was calculated as ROM.

The **degree of lameness** was examined with the dog walking 20 meters on a short leash. Gait evaluation was performed using the following subjective scoring system: 0 = no lameness observed, 1 = unclear lameness, 2 = obvious weight-bearing lameness, 3 = obvious lameness with intermittent non-weight-bearing steps, 4 = non-weight-bearing lameness.

Circumference of the stifle joint was quantified with a measuring tape[6] placed around the stifle joint at the level of the distal part of the patella as previously described (5). This measurement was taken in fully extended position of the joint.

To evaluate the **visual analogue scale** (VAS) the examiner set a mark on a 10 cm line, where 0 cm marked no subjective pain and 10 cm marked the worst possible pain as subjectively assessed by the blinded examiner. The measured value was defined as the distance from the left end of the scale to the mark set by the examiner (3).

For the modified **Glasgow Pain Scale** (GPS) (22) the examined criteria were demeanor, posture, vocalization, mobility, attention to surgical wound and response to touch. This allowed for a scoring of 0 to 24 possible points indicative of the dogs' physical and mental wellness with 0 being no pain and 24 being severe pain. GPS was completed after observation and manipulation of the dogs.

Statistical analysis

All statistical analyses were performed using a commercially available programme[7]. The variables ROM, GPS, stifle joint circumference, degree of lameness and VAS were analyzed by a two-way ANOVA with group as the independent factor and time point as

[2] Microsoft Excel 2010, Microsoft Corporation, Albuquerque, New Mexico, USA

[3] Cold compression device, pump model no. PPRT-01, wrap & gel pack model no. LCSW-12, LiteCure, LLC™ Companion Animal Health, Newark, Delaware, USA

[4] Infrared thermometer mini flash, model no. 31.1108, TFA Dostmann GmbH & Co. KG, Wertheim-Reicholzheim, Germany

[5] Goniometer, model no. REF 12.20600.001, Kirchner & Wilhelm GmbH & Co. KG Medizintechnik, Asperg, Germany

[6] Measuring tape profi, model no. 282171, William Prym Holding GmbH, Stolberg, Germany

[7] Statistical Analysis System SAS, SAS software, version 9.3, SAS Institute Inc., Cary, North Carolina, USA

Table 1
p-values of measured parameters compared between all study groups at all evaluated time points. CG = control group.

Tab. 1
p-Werte der untersuchten Parameter im Vergleich zwischen allen Studiengruppen zu allen untersuchten Messzeitpunkten. CG = Kontrollgruppe.

Comparison of groups	Range of motion	Degree of lameness[1]	Stifle joint circumference	Visual analogue scale	Glasgow Pain Scale
Before surgery					
CG vs. group I	0.2055	0.7965	0.9978	0.7992	0.8664
CG vs. group II	0.2255	0.0400*	0.8638	0.7992	0.3390
Group II vs. group I	0.9983	0.1479	0.8929	0.4177	0.6321
24 hours after surgery					
CG vs. group I	0.0004*	0.1928	0.6320	0.1305	0.0320*
CG vs. group II	0.0102*	0.3116	0.6461	0.3053	0.0474*
Group II vs. group I	0.4097	0.9523	0.9997	0.8714	0.9825
10 days after surgery					
CG vs. group I	0.1721	0.0031*	0.4919	0.0880	0.2320
CG vs. group II	0.7719	0.0031*	0.7056	0.3654	0.9846
Group II vs. group I	0.4846	1.0000	0.9349	0.6893	0.3023
42 days after surgery					
CG vs. group I	< 0.0001*	0.1070	0.0621	0.4606	0.1261
CG vs. group II	< 0.0001*	0.0356*	0.2165	0.2603	0.0310*
Group II vs. group I	0.2898	0.8588	0.7854	0.9152	0.7803

[1] Degree of lameness was significantly higher in group II before surgery and lower at the 42-day time point.
* Statistically significant values

factor with repeated measurements. Post hoc Tukey test was calculated for multiple pairwise comparisons, regarding the experiment-wise error rate. A p-value ≤ 0.05 was considered significant.

Results

Study population

Breeds were distributed as followed: mixed breed (n = 7), Labrador Retriever (n = 7), German Wirehaired Pointer (n = 2), Boxer (n = 2), Golden Retriever (n = 1), Newfoundland (n = 1), Chow Chow (n = 1), Bernese Mountain Dog (n = 1), Dalmatian (n = 1), Weimaraner (n = 1), Great Dane (n = 1), Old English Bulldog (n = 1), American Akita (n = 1), Rottweiler (n = 1), Bullmastiff (n = 1), American Staffordshire Terrier (n = 1). Bodyweight ranged from 26.8 kg to 73.0 kg with a mean of 36.1 ± 10.28 kg. The age ranged from 1.14 years to 10.79 years with a mean of 4.79 ± 2.52 years.

Meniscal tears occurred in 56.67 % of cases (n = 17) which were distributed as follows: 23.53% in group I (n = 4), 35.29% in group II (n = 6) and 41.18 % in the control group (n = 7). The differences in the distribution of meniscal tears between groups were not significant (p = 0.3867). All meniscal tears were identified in the medial meniscus and were treated with a partial meniscectomy of the damaged part of the meniscus. No major intraoperative or postoperative complications were observed. Two dogs in the control group showed minor wound inflammation at 10 days after surgery, which did not require additional treatment. No negative effects after CCT treatment were observed and all dogs tolerated the treatment. All dogs improved clinically, and no radiographic complications were observed. Bone healing was as expected for all patients at 42 days after surgery. All study participants were evaluated at all time points and none of the dogs were lost to follow-up.

Evaluated parameters

One day after surgery dogs in groups I and II showed a significant improvement for ROM (group I: p = 0.0004, group II: p = 0.0102) and GPS (group I: p = 0.0320, group II: p = 0.0474) compared to the control group (▶Table 1, ▶Fig. 1, ▶Fig. 2).

Ten days after surgery the only statistically significant difference between groups was observed in the degree of lameness with a statistically significant lower degree in groups I and II (both p = 0.0031) compared to the control group (▶Table 1, ▶Fig. 3). Before surgery there was a statistically significant higher degree of lameness in group II compared to the control group (p = 0.0400). Twenty-four hours after TPLO there was no statistically significant difference between these groups but at 42 days after surgery the control group showed a significantly higher degree of lameness compared to group II (p = 0.0356).

At the time point 42 days after surgery statistically significant greater ROM (p < 0.0001), lower GPS (p = 0.0310), and lower degree of lameness (p = 0.0356) were recorded in group II compared to the control group. Dogs in group I only showed statistically sig-

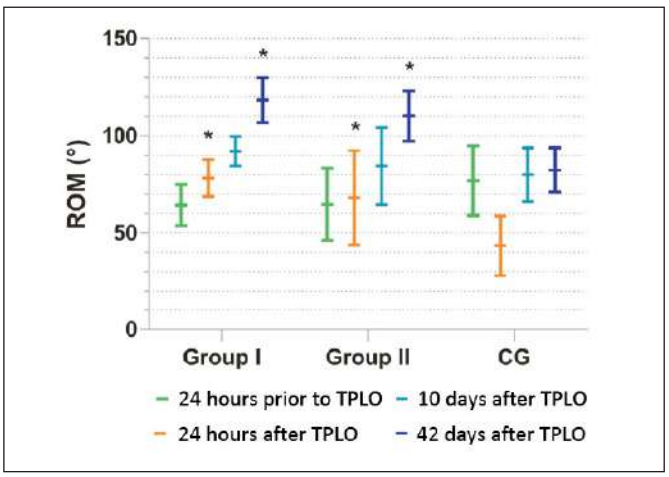

Fig. 1 Range of motion (ROM; mean ± standard deviation) of the stifle joints compared between study groups I and II and the control group (CG) at all measured time points (* indicates statistically significant difference of groups I and II compared to the control group at a given time point; see Table 1).

Abb. 1 Bewegungsumfang (ROM; Mittelwert ± Standardabweichung) der Kniegelenke im Vergleich zwischen den Studiengruppen I und II und der Kontrollgruppe (CG) zu allen evaluierten Messzeitpunkten (* markiert statistisch signifikante Unterschiede der Studiengruppen I und II im Vergleich zur Kontrollgruppe zu einem bestimmten Messzeitpunkt; siehe Tab. 1).

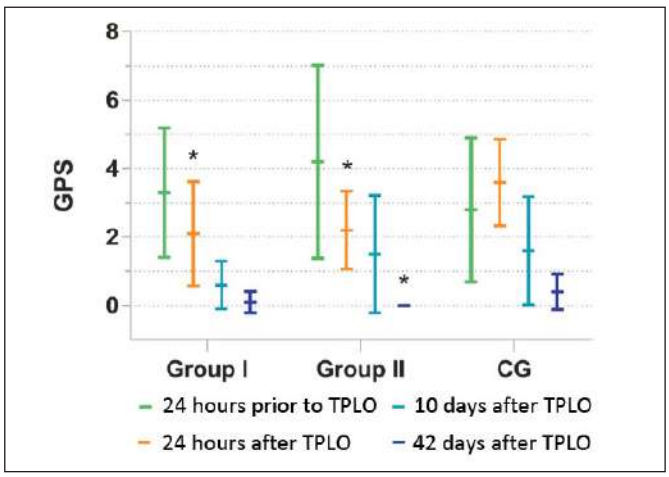

Fig. 2 Scores of the modified Glasgow Pain Scale (GPS, mean ± standard deviation) compared between study groups I and II and the control group (CG) at all measured time points (* indicates statistically significant difference of groups I and II compared to the control group at a given time point; see Table 1).

Abb. 2 Werte der modifzierten Glasgow Pain Scale (GPS; Mittelwert ± Standardabweichung) im Vergleich zwischen den Studiengruppen I und II und der Kontrollgruppe (CG) zu allen evaluierten Messzeitpunkten (* beschreibt statistisch signifikante Unterschiede der Studiengruppen I und II im Vergleich zu der Kontrollgruppe zu einem bestimmten Messzeitpunkt; siehe Tab. 1).

nificant differences for ROM ($p < 0.0001$) when compared to the control group (▶Table 1, ▶Fig. 1, ▶Fig. 2, ▶Fig. 3).

Regarding the parameters VAS and circumference of the stifle joint there were no statistically significant differences of groups I and II compared to the control group at any given time-point (▶Table 1, ▶Fig. 4, ▶Fig. 5). There were also no statistically significant differences between groups I and II in any of the parameters at any time point (▶Table 1).

When parameters were compared between time points 0 and 42 days after surgery most parameters were found to be significantly different between groups besides ROM in the control group ($p = 0.8029$) (▶Table 2).

Discussion

In the present study, we investigated a novel protocol of CCT for its effectiveness compared to a previously reported protocol (5) that showed beneficial effects in dogs undergoing TPLO. This novel protocol applies CCT once preoperatively and once immediately after surgery. While both protocols showed improvement in pain-related parameters, the previously established protocol appeared slightly superior at 42 days after surgery. The described novel protocol may provide a more feasible alternative of applying CCT in a clinical setting.

Only few veterinary clinical trials evaluating the effects of cryotherapy have been performed to date: In a randomized, blinded, placebo-controlled trial of dogs undergoing TPLO, postoperative CCT resulted in lower pain and lameness scores and an increased ROM one day after surgery. In that study no significant differences were found 2 weeks after surgery and at the 28-day time point an insufficient number of data sets were available for comparison (5). Our study findings are similar, however, we were able to show a longer lasting effect of the CCT. This may be related to the larger sample size, the difference in devices utilized or the study population. Another study showed that cold compression in combination with a bandage reduced soft tissue swelling at 72 hours after an extracapsular repair technique for cruciate ligament disease in dogs (27).

In human medicine positive effects of CCT are reported to have similar benefits: In one study (29) investigators showed that a postoperatively used cold-compression system resulted in lower pain scores, reduced need of analgesics and increased passive ROM compared to the application of ice alone after anterior cruciate ligament reconstruction surgery. One prospective trial (14) evaluating the efficacy of preoperative cryotherapy in humans undergoing arthroscopically assisted anterior cruciate ligament reconstruction has been conducted. In that study 53 patients were enrolled and randomized into two groups.

In the treatment group preoperative cryotherapy with an average duration of 60 minutes was performed using a commercial non-compressive cryotherapy unit, while there was no treatment in the control group. All patients received a dry sterile dressing, followed by a compressive wrap and a hinged knee brace which was

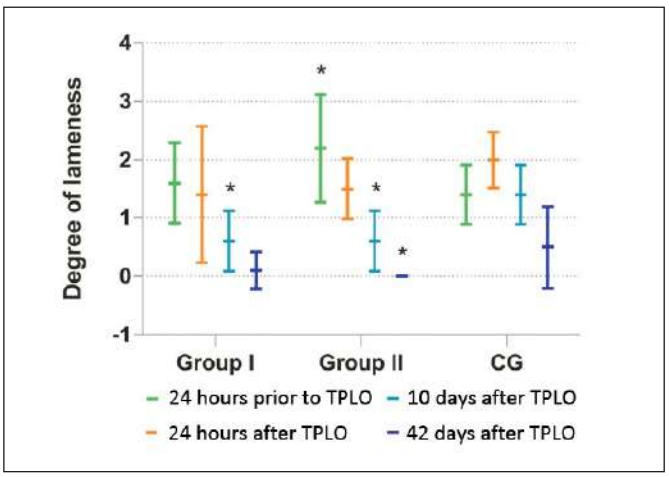

Fig. 3 Degree of lameness (mean ± standard deviation) compared between study groups I and II and the control group (CG) at all measured time points (* indicates statistically significant difference of groups I and II compared to the control group at a given time point; see Table 1).

Abb. 3 Lahmheitsgrad (Mittelwert ± Standardabweichung) im Vergleich zwischen den Studiengruppen I und II und der Kontrollgruppe (CG) zu allen evaluierten Messzeitpunkten (* beschreibt statistisch signifikante Unterschiede der Studiengruppen I und II im Vergleich zur Kontrollgruppe zu einem bestimmten Messzeitpunkt; siehe Tab. 1).

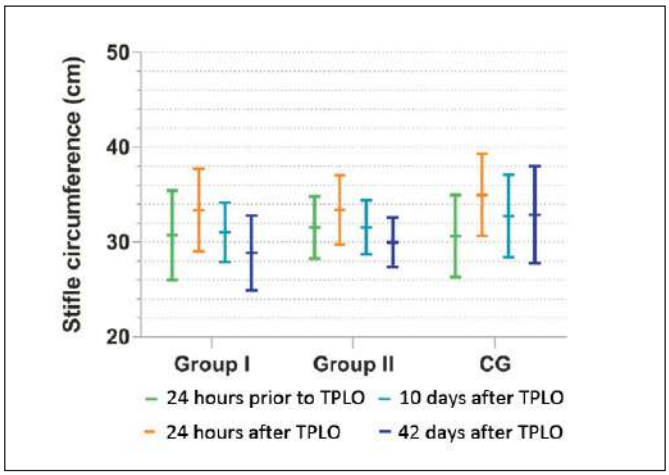

Fig. 4 Stifle joint circumference (mean ± standard deviation) compared between study groups I and II and the control group (CG) at all measured time points.

Abb. 4 Kniegelenkumfang (Mittelwert ± Standardabweichung) im Vergleich zwischen den Studiengruppen I und II und der Kontrollgruppe (CG) zu allen evaluierten Messzeitpunkten

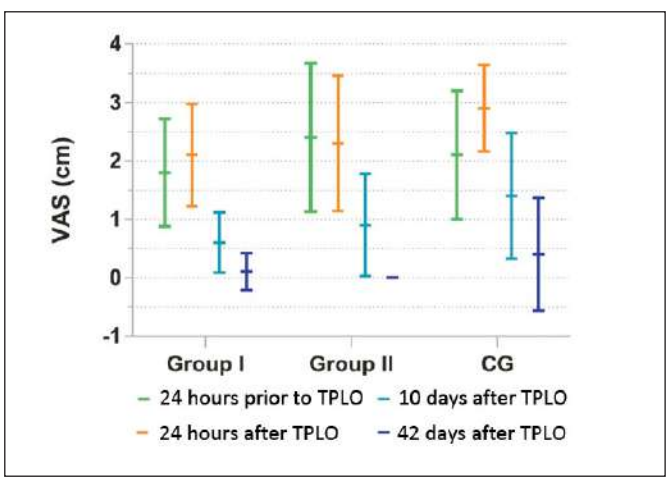

Fig. 5 Values of the visual analogue scale (VAS; mean ± standard deviation) for pain assessment compared between study groups I and II and the control group (CG) at all measured time points.

Abb. 5 Werte der visuellen Analogskala (VAS; Mittelwert ± Standardabweichung) zur Schmerzbeurteilung im Vergleich zwischen den Studiengruppen I und II und der Kontrollgruppe (CG) zu allen evaluierten Messzeitpunkten

locked in extension. The authors observed a significant reduction of reported pain in the first 36 hours after surgery which was measured via VAS. Furthermore, a significantly reduced consumption of pain relievers in the first 36 hours after surgery was reported. Preoperative cryotherapy is thought to work similarly to preoperative pharmacological interventions by providing preemptive analgesic effects. The importance of rehabilitation and multimodal and preemptive analgesia after orthopedic surgery has been recognized in veterinary medicine, and as such, treatment modalities without adverse effects are desirable (13). CCT represents such a modality, as confirmed by the present and previous studies (5, 27).

The choice of a single preoperative and postoperative CCT for our study protocol was based on previous studies in dogs and humans (5, 14, 18). We chose this protocol because it allows a very practical, simple clinically applicable protocol since patients are under general anaesthesia at these time points. Furthermore, postoperative CCT requires additional staff and the cooperation of the patient. However, our study design does not allow us to make any conclusions on the effectiveness of preoperative application of CCT alone. It is plausible that the one CCT applied postoperatively was the main reason for the observed benefits.

In our study, ROM was found to continuously improve for both CCT groups while a postoperative decrease was observed in the control group. This supports previous studies indicating that CCT provides a faster recovery (5, 27, 29).

The temperature of 4 °C was chosen, based on previous research (5) showing that this temperature is well tolerated in dogs and has analgesic potential to reduce the transmission velocity of pain signals. The relationship between application of cold and the potential to provide analgesia is thought to be linear up until 10 °C when neural transmission is blocked (7, 16). When temperatures below 0 °C are reached, it may cause tissue damage due to cold injury (7). The pressure of 50 mmHg was set based on former studies in humans (29) and dogs (5). The duration and treatment

	Range of motion	Degree of lameness	Stifle joint circumference	Visual analogue scale	Glasgow Pain Scale
Comparison of before/24 hours after surgery					
Group I	0.0095*	0.9047	0.0008*	0.7906	0.1451
Group II	0.9535	0.0449*	0.0135*	0.9941	0.0535
CG	< 0.0001*	0.0622	< 0.0001*	0.1930	0.5904
Comparison of before/10 days after surgery					
Group I	< 0.0001*	0.0110*	0.9574	0.0050*	0.0002*
Group II	0.0267*	< 0.0001*	1.0000	0.0039*	0.0057*
CG	0.9579	1.0000	0.0104*	0.2955	0.2509
Comparison of before/42 days after surgery					
Group I	< 0.0001*	0.0001*	0.0176*	< 0.0001*	< 0.0001*
Group II	< 0.0001*	< 0.0001*	0.0460*	< 0.0001*	< 0.0001*
CG	0.8029	0.0027*	0.0059*	0.0009*	0.0039*
Comparison of 24 hours/10 days after surgery					
Group I	0.0101*	0.0530	0.0029*	0.0004*	0.0468*
Group II	0.0836	0.0068*	0.0147*	0.0073*	0.7800
CG	< 0.0001*	0.0622	0.0067*	0.0034*	0.0186*
Comparison of 24 hours/42 days after surgery					
Group I	< 0.0001*	0.0008*	< 0.0001*	< 0.0001*	0.0052*
Group II	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	0.0292*
CG	< 0.0001*	< 0.0001*	0.0117*	< 0.0001*	0.0001*
Comparison of 10 days/42 days after surgery					
Group I	< 0.0001*	0.3465	0.0051*	0.4256	0.7932
Group II	0.0028*	0.1037	0.0425*	0.1271	0.2025
CG	0.9776	0.0027*	0.9959	0.0713	0.2509

* Statistically significant values

Table 2
p-values of measured parameters compared for each study group as a comparison between evaluated time points. CG = control group.

Tab. 2
Vergleich der p-Werte zwischen den drei Studiengruppen zu den einzelnen Messzeitpunkten. CG = Kontrollgruppe.

intervals of CCT were selected on the basis of current recommendations regarding the use of cold compression in veterinary medicine (7) and former studies (5) related to the practicability in a clinical surrounding.

Although Priddy et al. (26) reported an owner satisfaction of 93% after TPLO, complications were reported in 14.8% up to 34% of cases (1, 6). Short-term complications, such as swelling, incision line inflammation, edema or bruising were reported in up to 9.3% of cases (31). Additional medical treatment and extended postoperative management may be necessary for minor complications, such as swelling, limb edema, hematoma, lameness and postoperative pain (4, 6, 26, 31). Avoiding these complications allows for a more rapid recovery from surgery and less need for postoperative care. In our study we did not experience any short-term complications except for two dogs in the control group showing minor signs of wound inflammation 10 days after surgery. Further investigation into these complications with a larger sample size is needed since this was not a direct objective of the study.

Even though evaluation of pain in domestic animals is difficult, the VAS is a simple way of assessing pain and a frequently used method in animal studies (10, 11). Another way of evaluating the amount of pain is by means of several observations and interactions with the animal via the behavior-based modified Glasgow Pain Scale (22). In our study we did not find any significant results between groups for the VAS. This may be explained by the subjective aspect of this pain scale, the multidimensional characteristics of pain or that dogs that underwent the examination were too irritated by the foreign environment and the examiner's manipulation to show adequate signs of pain.

Conclusion for practice

Cold compression therapy can aid to reduce pain-related parameters if used once pre- and postoperatively after tibial plateau leveling osteotomy in dogs.

Limitations of the present study include the variability inherent in a natural model, the sample size and lack of a study group receiving preoperative CCT only. We also did not identify a statistical difference in distribution of dogs with meniscal tears/arthrotomies between groups.

Moreover, we do not know which of the two CCT applications in group I created the beneficial effects. Further studies could investigate the effects of a single preoperative application of CCT and a single postoperative application of CCT with the established protocol. However, the utilized protocol can easily be followed in a clinical setting without additional staffing and therefore such studies may not be necessary.

Conflict of interest

The cold compression wraps with inlays and the pump device used for the study were provided by Companion Animal Health, 250 Corporate Blvd, Newark (Delaware). Neither of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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