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Treatment of Medial Shoulder Joint Instability by Stabilization with an Arthroscopically Guided Prosthetic Ligament: A Cadaveric Feasibility Study in Dogs

Marie Llido[1] Véronique Livet[2] Claude Carozzo[3,4] Éric Viguier[3,4] Thibaut Cachon[3,4]

[1] Small Animal Surgery Department, School of Veterinary Medicine, University of Montreal, Saint-Hyacinthe, Québec, Canada
[2] Lumbry Park Veterinary Specialists, Alton, United Kingdom
[3] Small Animal Surgery Department, Lyon University, VetAgro Sup, Marcy l'Etoile, France
[4] Research Unit ICE, UPSP 2016-A104, Lyon University, VetAgro Sup, Marcy l'Etoile, France

Address for correspondence Marie Llido, DMV, IPSAV, School of Veterinary Medicine, University of Montreal, 3200 rue Sicotte, Saint-Hyacinthe, Québec, J2S 2M2, Canada (e-mail: llido.marie@gmail.com).

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Abstract

Objective The aim of this study was to assess the feasibility and efficiency of an arthroscopically guided ligamentoplasty of the medial glenohumeral ligament to treat medial shoulder joint instability.

Study Design Six Beagle cadavers were used (12 limbs). Both arms of the medial glenohumeral ligament were severed using arthroscopic guidance. Arthroscopically guided reconstruction of the ligament was performed. Threaded sutures were fixed with a bone anchor on the medial aspect of the glenoidal cavity of the scapula, passed through a humeral tunnel and finally tensioned with a suture button on lateral aspect of the humerus. Shoulder abduction angles were measured before and after the section of the medial glenohumeral ligament, and following the surgery. Two orthogonal radiographic projections and dissections were performed after each procedure to grade the placement of the implants.

Results Surgical repairs were achieved in 10 out of 12 limbs. The abduction angles after repair with ligamentoplasty were not significantly different from the abduction angles measured before the section of the medial glenohumeral ligament.

Conclusion Arthroscopically guided ligamentoplasty with a scapular bone anchor and a humeral drilling tunnel is feasible in cadavers, and efficient to restore acutely shoulder abduction angle in a minimally invasive manner. Further clinical studies are required to assess *in vivo* results.

Keywords
- minimally-invasive surgery
- ligamentoplasty
- dog
- medial shoulder instability
- arthroscopy

Introduction

Shoulder lameness is a common finding in dogs[1–3] and shoulder joint instability is one of the most common causes with a prevalence ranging from 33 to 64%.[1,4–7] Among those instabilities medial shoulder instability is the most frequent with a prevalence of 78%.[2] Most of the time, tears of the medial glenohumeral ligament,[8,9] lesions of the articular capsule or the cuff muscles[10] especially subscapularis muscle tendon are responsible for the disease. Measurement of

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maximum abduction angle of the shoulder joint has been described to be an easily feasible diagnostic tool to assess medial shoulder laxity.[9] However, some recent studies showed that maximum shoulder abduction angles varied greatly and could reach up to 75 degrees un normal joints, questioning the reliability[11,12] and specificity[13] of this test.

Conservative management can be attempted first, aiming to temporarily reduce abduction movement of the shoulder.[14] It consists of exercise restriction, hobbles and pain management. Unfortunately, conservative treatment has three time less chance to have a favourable outcome than surgical treatment.[2]

Several surgical approaches have been described. Medial biceps tendon transposition[15] or subscapularis muscle tendon imbrication[16] can be used to reinforce the articular capsule and provide resistance to medial movements. It has the disadvantage not to correct rotatory movements. Finally, the replacement of the medial glenohumeral ligament with prosthesis can be accomplished. Ninety per cent of dogs treated with ligament reconstruction had a good to excellent function after surgery.[17] Different ligamentoplasty techniques have been described: three anchors placed at the distal and proximal insertion points of the medial glenohumeral ligament,[18] inverted V-shaped extracapsular stabilization technique[19] or humeral and scapular bone tunnels with a multi-strand suture tensioned with buttons.[20] This last technique provides an excellent outcome in 77% of dogs. Arthrodesis of the shoulder may be considered when osteoarthritis is too advanced.[21,22] Those techniques have been developed with an open approach. In human medicine, minimally invasive surgery is well established and reduce postoperative pain with faster recovery. More recently, Penelas and colleagues[23] showed a promising and safe technique of arthroscopic imbrication of the medial glenohumeral ligament and the subscapularis tendon with knotless anchors.

Our study was designed to assess the feasibility of an arthroscopically guided ligamentoplasty technique with surgical anchor to repair medial shoulder instability. The goal was to create a standardized procedure and assess the feasibility and ability of this technique to reduce shoulder abduction angle. Our hypothesis was that this technique would be feasible and efficiently restore normal shoulder abduction angle.

Materials and Methods

Dogs

Six Beagle dogs were euthanatized for reason unrelated to this study and had no previous pathology affecting limbs (no abnormalities found during orthopaedic and radiographic examinations). Both shoulders were used for each dog. The study was approved by the Clinical Research Committee VetAgro Sup, Marcy l'Etoile, France (Ethics Committee number 1810). Dogs cadavers were allowed to thaw for 24 hours at room temperature before all testing.

Surgical Induction of Medial Shoulder Instability

Each dog was clipped, prepped and draped aseptically. The subject was placed in lateral recumbency with the desired shoulder facing up. A standard lateral approach was performed with a caudolateral camera portal and a craniolateral instrument portal. A complete exploration of the shoulder joint was performed with a 2.7 mm 30 degrees oblique rigid arthroscope (Karl Storz, Mittelstrasse, Germany). Light source and camera were plugged on a compact unit (Medipack, Karl Storz, Mittelstrasse, Germany). Both branches of the medial glenohumeral ligament were then transected with scissors to create a medial shoulder instability. Patient was then shifted in dorsal recumbency with the limb of interest hanged while keeping the arthroscope in the joint. All procedures were performed by a board-certified surgeon (TC).

Arthroscopically Guided Ligamentoplasty

The arthroscope was maintained in a caudolateral position to observe the medial part of the glenoid. An 18-gauge needle was introduced from craniomedial to caudolateral (toward the arthroscope) cranially to the subscapular muscle to minimize muscular iatrogenic damages. Once the needle was placed adequately and seen, a 2-cm incision was made through the skin, soft tissues and joint capsule with an 11-scalpel blade following the needle. An end-toothed guide (Spear with circumferential teeth, trocar tip obturator, reusable – AR-1906, Arthrex Vet Systems, Arthrex Inc., Naples, Florida, United States) was introduced through the incision and secured on the labrum in the middle of the two branches of the medial glenohumeral ligament on the glenoid. A 1.5 mm Kirschner wire was inserted in the guide and drilled in the labrum (►**Fig. 1A**). Successive dilators were then inserted along the Kirschner wire to dissect atraumatically the surrounding tissues. A 5 mm diameter dilator was then maintained, while the Kirschner wire was removed which allowed to localize the pre-drilled hole. Threaded suture anchors (FASTak Suture Anchor 2.8 mm × 11.7 mm w/cannulated inserter and #2 Fiber Wire, Arthrex Vet Systems, Arthrex Inc., Naples, Florida, United States) with a nonabsorbable, multi-strand suture with a core of ultra-high molecular weight polyethylene and a braided jacket of polyester were used. The inserter was short and self-drilling (►**Fig. 1B**). The cannula with the anchor was inserted in the dilator and the anchor was tightened so that the transverse laser marking was at the level of the osteocartilagenous surface (►**Fig. 1C**). Once properly tightened, sutures were unlocked and the handle was removed leaving the anchor attached to the sutures (►**Fig. 1D**). The dilator was also removed. The humeral drilling was then performed with a 2.0 mm Steinmann pin going from the medial to the lateral side with a minimal lateral approach to see the exit point of the tunnel. On the medial side, the skin incision performed to place the anchor was used to introduce the Steinmann pin. The insertion drilling point was centred on the humeral head distally to the articular capsule and was oriented toward the greater tubercle. The tunnel was then enlarged with a 3.0 mm cannulated drill bit from medial to lateral. The Steinmann pin was removed, a wire passer was introduced within the drill bit to grab the sutures still attached to the anchor on the medial side and pass them to the lateral side (►**Fig. 2**). The drill bit was then removed from the lateral side. The sutures

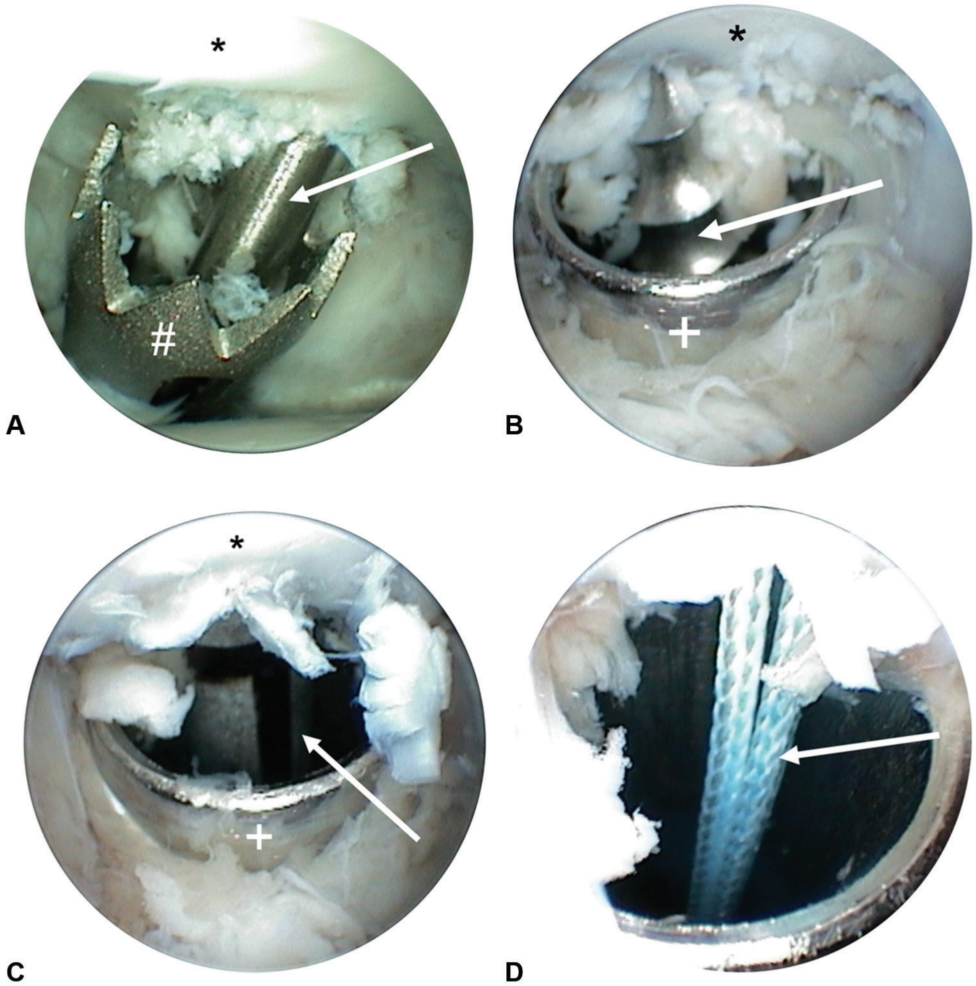

Fig. 1 Description of the procedure: (**A**) Arthroscopic view of the end-toothed guide (#) securing the position on the labrum to drill precisely the Kirschner wire (white arrow) in the labrum (*). (**B**) Arthroscopic view of the anchor tip (white arrow) positioned in the previously drilled hole in the labrum (*) going through the dilator (+) placed before introducing the anchor to dissect surrounding soft tissue and facilitate access for the anchor. (**C**) Arthroscopic view of the anchor with the black marks once screwed within the dilator (+). (**D**) Arthroscopic view once sutures unlocked (white arrow) and handle removed after appropriate tightening of the anchor.

were inserted in a two-hole button (two/four-hole titanium Suture Buttons Arthrex, Arthrex Vet Systems, Arthrex Inc., Naples, Florida, United States). The button was placed as close as possible to the bone and sutures were tightened with locking knots (►**Fig. 3**). Tensioning was performed through the minimal lateral approach previously described. Consequently, few soft tissues became trapped in the suture while tensioning. On the medial side, the skin incision used to introduce the anchor was also used to place the Steinmann pin to limit soft tissue entrapment. The tension was applied according to the surgeon appreciation with the shoulder positioned in a slight adduction. All procedures were performed by a board-certified surgeon (TC).

Abduction Angle Measurements

Abduction angle measurements were performed as previously described by Cook and colleagues[9] before and after transection of the medial glenohumeral ligament, and after the ligamentoplasty, by the use of a universal plastic goniometer. The subject was positioned in lateral recumbency. The measurements were achieved on the upper limb by the operator. The acromion process was grasped with the thumb and the forefinger of the same hand to prevent any movement of the scapula. The carpus was grasped with the other hand. The shoulder was held in extension, at a neutral angle and the thoracic limb was then abducted. All measurements were performed in triplicate by the same operators (VL, resident surgeon & TC, board-certified surgeon).

Radiographs Evaluation and Implant Placement

After each procedure, two standard radiographic projections (mediolateral and caudocranial) of the shoulder were taken. The radiographic landmarks of the medial glenohumeral ligament insertions, previously described,[24] were used to assess the quality of the anchor placement and humeral drilling. A 4×4 grid pattern was applied on the scapula on the mediolateral projection to localize the proximal insertions of the two branches of the medial glenohumeral

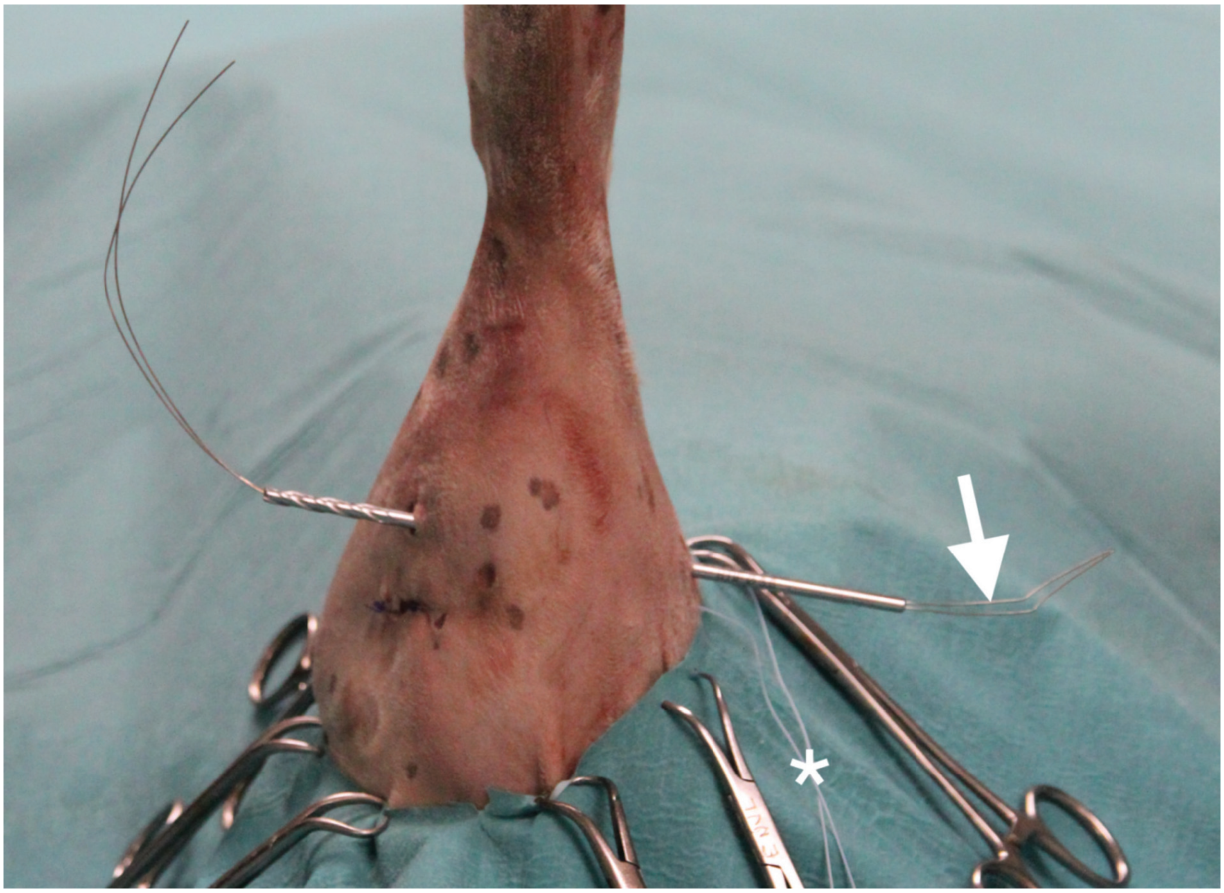

Fig. 2 Craniocaudal view of the humeral tunnel with the drill bit still inside. The passer wire (white arrow) is inserted in the drill bit to grab the sutures (white asterisk) attached to the anchor on the medial side and pass them through the bone tunnel to tensioned them on the lateral side.

ligament. The grid was numbered from 1 to 4 craniocaudally and A to D dorsoventrally. C1 and C4 were, respectively, considered the area of insertion of the cranial and caudal branches of the medial glenohumeral ligament (►**Fig. 4A**). A similar method was used on the humerus for the distal insertion. C3 was considered the area of insertion of the distal branch of the medial glenohumeral ligament (►**Fig. 4B**). On the craniocaudal projection, a circular grid was applied to localize the distal insertions. The dials were numbered clockwise from 1 to 12, the first one located between noon and 1. The dial 10 was considered as the distal area of insertion (►**Fig. 4C**). Based on these landmarks, the anchor placement in the scapula and the humeral drilling entry point were assessed. For the mediolateral projection, the anchor placement and the humeral tunnel distal insertion were graded from 0 to 2 as described in ►**Fig. 4A** and **B**. For the craniocaudal projection, the humeral tunnel distal insertion was graded from 0 to 2 as described in ►**Fig. 4C**. A subjective scoring was assigned for bone anchoring, tunnel inclination and button apposition. Each of those criterium were graded from 0 to 2. 0 being a torn anchor, inadequate inclination or apposition; 2 being ideal bone anchoring, 30 degrees angle inclination humeral bone tunnel (to avoid frictions on the suture material) or ideal apposition to provide appropriate tension. For each shoulder, a global positioning score out of 10 was obtained by adding the anchor positioning, the humeral tunnel and the button positioning score. To give equal importance to the proximal and the distal insertions, a corrective factor of ⅔ was applied to the initial humeral tunnel score. A score for global positioning of 0 to 1 was considered as failure, 2 to 3 poor, between 4 and 6 average, 7to 8 good and 9 to 10 excellent.

Dissection

A thorough dissection of the shoulder joint was performed after each procedure to assess any potential iatrogenic lesions induced by the arthroscopic approach and to evaluate macroscopically the implant positioning in the joint.

Statistical Analysis

Statistical analysis of abduction angles was performed using GraphPad Prism. Normal distribution of data was confirmed with a D̀Agostino-Pearson test. Means ± standard deviation (SD) of the abduction angles at each stage of the procedure were determined, and data were compared for significant differences with a Fischer's exact *t*-test. The level of significance was set at $p < 0.05$. Means ± SD of the subjective positioning scoring for each part of the implant were determined and presented as descriptive data.

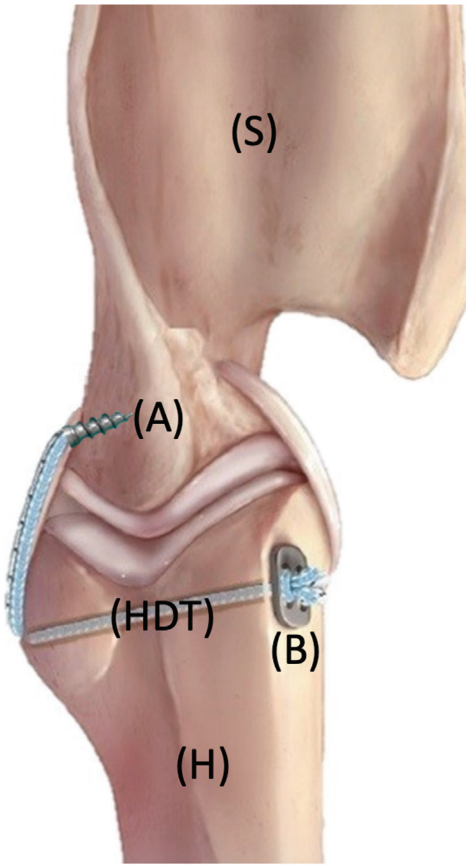

Fig. 3 Ligamentoplasty with a threaded suture anchor (**A**) secured in the medial labrum of the scapula at mid-distance between insertions of the two branches of the medial glenohumeral ligament, sutures are passed through a humeral drilling tunnel (HDT) and a button (**B**) is used to tensioned the sutures between the scapula (S) and the humerus (H).

Results

Animals

A total of six dogs and 12 limbs were tested. Two male and four female Beagle dog cadavers with a mean age of 16.2 ± 2.6 months old and mean weight of 12 ± 1.2 kg were used.

Procedure

Transection of the two branches of the medial glenohumeral ligament by arthroscopy was successfully performed for all the shoulders. The ligamentoplasty was successfully performed in 10 out of 12 shoulders (83.3%). In the two remaining shoulders, the anchor was torn off on the immediate postoperative radiographs. The range of motion of the shoulder was not altered after the procedure either in flexion or extension.

Abduction Angle

Abduction angle measurements at each stage are presented in ►**Appendix Table 1** (available in the online version). Mean abduction angle before the procedure was 22.8 ± 2.9 degrees. After medial glenohumeral ligament transection, mean abduction angle was 52.2 ± 3.3 degrees. Once the procedure was performed, mean abduction angle was 20 ± 3.7 degrees. Abduction angles after section were significantly larger ($p < 0.0001$) than initial ones with intact medial glenohumeral ligament. There was no significant difference between initial and post-ligamentoplasty abduction angles.

Positioning Evaluation

Positioning grading and evaluation are presented in ►**Appendix Table 2** (available in the online version). Mean global positioning was $7.2/10 \pm 1.6$ with a mean positioning of the anchor $2.6/4 \pm 1.2$, of the humeral drilling $4.2/6 \pm 1.0$ and button $1.8/2 \pm 0.6$. Three ligamentoplasties were considered excellent (►**Fig. 5A**, **B**), six were good, one was average and finally two were considered as failure. The two placements that were evaluated as failure were because the anchor was torn off when radiographs were performed (►**Fig. 5C**, **D**).

Dissection

On the medial side, some minor lesions of the pectoral muscle and the subscapularis muscle due to the approach were assessed. In one case, there was a minor lesion of the deltoid muscle. No articular cartilage damage was noticed at the level of the glenoid cavity.

Discussion

The goal of our study was to create a standardized procedure to treat the medial shoulder joint instability and assess the feasibility and ability of this technique to reduce shoulder abduction angle. Our study showed the feasibility of a new arthroscopically guided ligamentoplasty technique with surgical anchor to stabilize the shoulder joint medial compartment. The procedure was successfully performed in 10/12 shoulders with 9/12 good to excellent implants positioning. It allowed restoration of normal shoulder abduction angle with no significant difference between angles before section of medial glenohumeral ligament and after the repair.

Two anchors were torn off at the time of post-procedure radiographs and would have required a revision surgery. These two failures happened at the beginning of the learning process. The authors considered that it may be due to placement of the anchor too tangential on the glenoid labrum and that bone purchase was insufficient. It was not possible to locate those anchors on the map because at the time of radiographs they were already torn. When the anchor was not torn off, the positioning was good to excellent in 9/10 shoulders. When compared with a previously described ligamentoplasty technique, relying on two drilling tunnel[20] within the bone, it appears obvious that using an anchor is technically more challenging than a drilling tunnel. Indeed, mispositioning risk factors are numerous. In this technique, the two arms of the medial glenohumeral ligament are replaced by a single anchor, slightly altering the biomechanical properties of the reconstructed ligament. We elected to replace both arms by one anchor based on the fact that it has been previously showed that the cranial branch of the medial glenohumeral ligament is much more responsible for stability than its caudal counterpart, even if an isolated transection

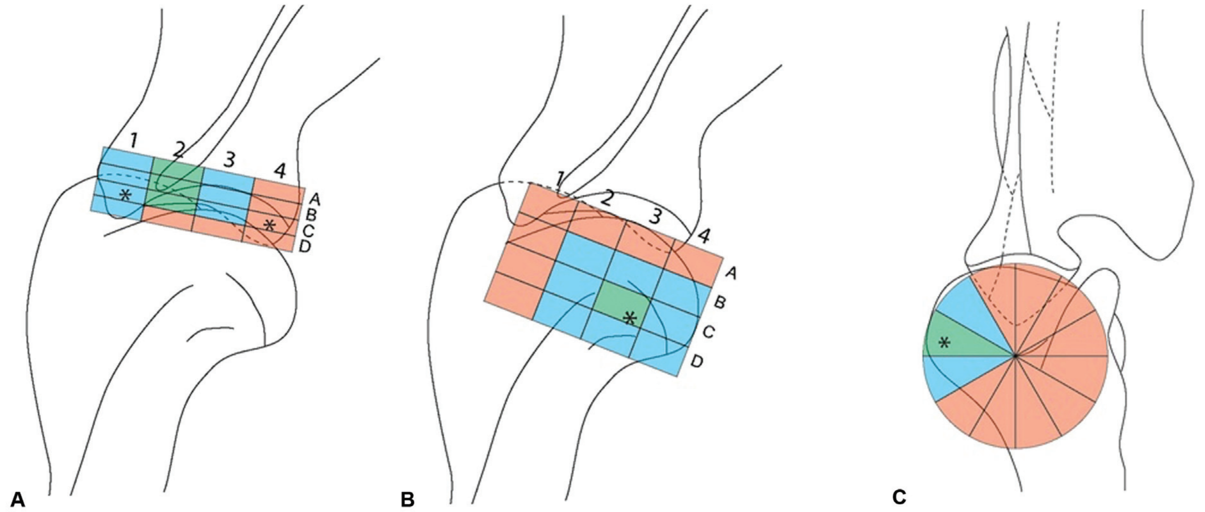

Fig. 4 (A) Mediolateral view of the shoulder with a 4 × 4 grid to assess anchor positioning in the scapula. The two asterisks are showing the cranial and the caudal arms of the medial glenohumeral ligament insertions. (B) Mediolateral view of the shoulder with a 4 × 4 grid to assess humeral drilling tunnel entry point. The asterisk is showing the distal insertion of the medial glenohumeral ligament. (C) Craniocaudal view of the shoulder to assess the humeral drilling tunnel entry point with a circle divided in 12 wedges. The asterisk is showing the distal insertion of the medial glenohumeral ligament. The area coloured in green was defined as optimal positioning scored +2, the blue area was defined as suboptimal positioning scored +1 and the orange area was defined as inadequate scored 0.

did not induce luxation.[25] The cranial part of the glenoidal rim is thinner and inserting an anchor in this area would decrease the chance to have a proper bone anchorage and increase the risk of tearing off the anchor. Placement of the anchor at the midway point is, therefore, a compromise between these two assessments. Placing an anchor on the caudal part of the glenoid cavity would be feasible as described by a previous study[23] but would require a caudomedial port which is challenging and would result in a less accurate anchor placement. Therefore, using two anchors to replace each branch of the medial glenohumeral ligament would be feasible but achieving adequate bone anchorage for both anchors would be more technically challenging and will require further studies.

The size of the anchor (2.8 mm) was adjusted to the size of the dogs used in the study (mean weight of 12 kg). Similar threaded suture anchors are available in 4.5, 5.5 and 6.5 mm diameter (BioComposite Corkscrew FT Suture Anchor, 4.5 × 14.7 mm w/two 1.3 mm Suture Tape, Arthrex Vet Systems, Arthrex Inc., Naples, Florida, United States) and could be used on bigger dogs. In human medicine, impacted anchor is also usually used for repair of shoulder ligaments defects with a good outcome for return to physical activity (74–89%),[26,27] supporting the idea that this technique could be used in dogs.

Abduction angle measurement allowed to assess the efficiency of the technique described here and to compare it to the initial study describing for the first-time abduction angles measurement.[9] In our study, the mean physiological angle was 22.8 ± 2.9 degrees which is significantly smaller than the angles described by Cook and colleagues (32.6 ± 2 degrees). However, Beagle dogs used in this study were much smaller (mean weight of 12 kg compared with 26.2 kg in the study of Cook) which can induce some bias. Once the medial glenohumeral ligament was severed, mean abduction angle was 52.2 ± 3 degrees which is coherent with the reference value (53.7 ± 4.7 degrees) and significantly increased compared with initial angles measurements. There was no significant difference in abduction angles following the restorative procedure (20 ± 3.7 degrees) compared with initial measurements. Therefore, this procedure is efficient to restore physiologic abduction angle in 100% of successful cases (10/10). Our final abduction angles were comparable to previously described results obtained with other corrective surgical techniques such as tightrope ligamentoplasty,[20] subscapularis muscle imbrication[16] or radio frequency-induced thermal capsulorrhaphy.[28]

This technique was performed in a minimally invasive manner. It has been previously described in cases of cranial cruciate ligament ruptures that recovery is faster[29] with arthroscopy when compared with arthrotomy. Indeed, anatomical reconstruction and arthrotomy would require a major dissection increasing the likelihood of iatrogenic damages and postoperative discomfort in the perspective of clinical use. Our approach induces minimal damage to soft tissue as confirmed by dissection. Very few lesions were seen in the pectoral and subscapularis muscles, while a minimal lesion in the deltoid muscle was observed in only one case. This technique can be used in a lot of facilities because it only requires basic equipment for orthopaedic procedures and arthroscopy. The use of peroperative fluoroscopy is not required contrary to other described techniques that imply exposition of the medical staff to radiation.[23] The approach used in this technique was based on a previous study that showed that a craniomedial approach allows a proper positioning in 90% of cases regarding the insertion of the medial glenohumeral ligament.[23] It was performed mainly with a medial approach and minimal lateral approach in comparison with tightrope ligamentoplasty.[20] Using a minimal lateral approach reduced the iatrogenic risk of lesion to the supra-scapularis nerve.

Fig. 5 (**A**) Mediolateral and (**B**) craniocaudal radiographs of the ligamentoplasty considered excellent (left thoracic shoulder joint of dog no 4). (**C**) Mediolateral and (**D**) craniocaudal radiographs of a ligamentoplasty considered as failure with the anchor torn-off at time of radiographs (right thoracic shoulder joint of dog no 2).

Our study has some limitations. The population of dogs used in this study is small, quite uniform and may limit direct interpretation for bigger dogs. Medial shoulder instability was created by transecting both branches of medial glenohumeral ligament. Transection was acute and it is reasonable to believe that *in vivo* tearing is more progressive and also involves joint capsule and other stabilizers. One of the main limitations of our study is our outcome evaluation that relies on the measurement of the abduction angles. This diagnostic technique has recently been proven to be not as reliable and repeatable as initially suggested.[11,12] In our study, the surgeon assessed the tension to apply on the sutures to reduce the instability. Further studies correlating the reduction of the abduction angle with the tension applied on the sutures would be interesting. Evaluation of implants positioning was achieved on two orthogonal radiograph projections which did not allow three-dimensional localization. Ideally, more advanced imaging techniques would have been required such as tomodensitometry or magnetic resonance imaging which were not in the scope of this study. For instance, a previous study used tomodensitometry to evaluate the quality of bone anchoring and orientation of the implants.[23]

In conclusion, our study described a new arthroscopically guided ligamentoplasty technique with a bone anchor and a humeral drilling tunnel. The study showed that this technique is feasible and safe in cadavers and efficient to restore shoulder abduction angle to their physiological levels. The glenoid rim is really narrow and tearing off is the main risk of this technique. It could be a reliable technique to restore stability of the shoulder medial compartment in a minimally invasive manner if supported by further clinical studies focusing on safety, resistance to failure of the implant in time and adaptability of the technique to several breeds of dog. Additional studies are required to assess the proper tension to apply on the sutures to reduce adequately the abduction angle.

Note

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Author Contributions

M.L., V.L. and T.C. contributed to study design, acquisition of data and data analysis and interpretation. C.C and E.V. contributed to conception of study. All authors drafted, revised and approved the submitted manuscript.

Conflict of Interest

T.C. is a paid consultant for Arthrex.

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