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Long-term evaluation of bicipital tenodesis with T-staple in three dogs: a case report

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ABSTRACT: The purpose of this report is to describe the T-staple tenodesis of biceps brachii in three client-owned dogs and long-term ultrasonographic follow-ups. The orthopaedic examination revealed grade 2/4 (n = 2) and 3/4 (n = 1) lameness, moderate pain on passive movement and positivity to the tendon biceps test with a complete extension of the elbow during the flexion of the shoulder (Cases 1 and 2). Ultrasound examination was crucial for diagnosis of partial or complete rupture and tenosynovitis of biceps tendon. Surgical tenodesis was carried out with a metal T-staple. One-year ultrasound follow-up was performed, confirming the correct integration of the staple on the bicipital fibres and the absence of macroscopic tendon injury or degenerative disease. The results suggest that the metal T-staple could be a good alternative for bicipital tenodesis in dogs.

Keywords: biceps brachii tendon; ultrasonography; staple; dog

Lesions of the biceps tendon have been described as the third most common cause of shoulder lameness after shoulder instability and osteochondritis dissecans of the humeral head in dogs (Bardet 1999). In veterinary practice, avulsion of the biceps brachii tendon from the supraglenoid tubercle, tendon rupture and bicipital tenosynovitis have been surgically treated with tenodesis or tenotomy (Bruce et al. 2000; Wall and Taylor 2002; Adamiak and Szalecki 2003; Cook et al. 2005). The biceps tenodesis procedure involves cutting the biceps tendon close to its insertion on the supraglenoid tubercle and then anchoring the tendon along its anatomical course more distally along the humerus. Several different anchoring techniques have been described using arthrotomy or arthroscopy (Piermattei and Flo 1997; Adamiak and Szalecki 2003; Innes and Brown 2004; Cook et al. 2005). Otherwise, the biceps tenotomy procedure involves transecting the tendon and leaving it free, using arthrotomy, arthroscopy, or in a percutaneous procedures (Piermattei and Flo 1997; Venturini et al. 1998; Denny and Butterworth 2000; Cook et al. 2005; Esterline et al. 2005; Bergenhuyzen et al. 2010).

The purpose of this article is to report the clinical and radiological outcomes as well as the ultrasonographic findings after the execution of the biceps tenodesis procedure on three dogs.

Case description

Three client-owned dogs were presented at the Department of Veterinary Medical Sciences, University of Bologna, for investigation of moderate-to-severe forelimb lameness. Clinical examination, diagnostic imaging and surgical treatment were performed as follows.

Case 1. An eighteen-month-old male working Hungarian Vizsla dog, weighing 26 kg, was referred with a four months history of right forelimb lameness. The orthopaedic examination revealed grade 2 (out of 4) lameness, moderate pain on passive movement, and positivity to the tendon biceps test with the complete extension of the elbow during the flexion of the shoulder (Wiemer et al. 2007). Radiographic examination of the right shoulder in a medio-lateral projection revealed signs of moderate osteoarthritis on the cranial aspect of the proximal humerus with mild osteophyte formation (range of 1–2 mm) on the intertubercular groove, as well as an irregular supraglenoid tubercle.

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Ultrasound examination of the right shoulder performed with a 10 MHz linear probe, revealed a partial rupture of the biceps brachii tendon with incomplete disruption of the normal fibrillar pattern of the tendon next to its insertion on the supraglenoid tubercle. The surface of the tubercle appeared rough and bumpy and small hyperechoic bone fragments were attached to the tendon. Moderate and inhomogeneous hypoechoic fluid was present in the tendon sheath as well as in the articular space. Distally, the mean echogenicity [scale of 256 grey levels (0 = black; 255 = white)] of the tendon along the intertubercular groove was in the normal range compared with that of the contralateral limb (Spinella et al. 2013). This aspect was consistent with the diagnosis of partial biceps tendon avulsion and, according to Kramer's classification, grade 2 tenosynovitis (Kramer et al. 2001).

Case 2. A six-year-old female working Irish Red Setter dog, weighing 21 kg, showed lameness of the left forelimb of one-month duration due to a trauma. An anti-inflammatory drug had been administered without improvement. On initial evaluation the dog showed a grade 2 (out of 4) lameness, moderate pain, hypotrophy of the shoulder muscles, and he was positive to the biceps tendon test performed with shoulder flexion and elbow extension.

Radiographic views of the left shoulder revealed a defect of the supraglenoid tubercle which was irregular, and a bone fragment on the cranial aspect of the tubercle, as well as a soft mineralisation in the proximal part of the bicipital groove.

During ultrasound of the left shoulder joint, performed with a 10 MHz linear probe, a longitudinal scan revealed complete rupture of the biceps tendon with complete disruption of the normal fibrillar pattern in the proximal part. The supraglenoid tubercle appeared rough with a small fragment evident in the articular surface (Figure 1A). Moreover, around the suprascapular tendon insertion the collection of heterogeneous and hypoechoic fluid was observed. The mean echogenicity of the left bicipital tendon along the intertubercular groove was in the normal range compared to that of the contralateral limb. These findings led to the diagnosis of complete brachii biceps tendon rupture, grade 2 bicipital tenosynovitis and suprascapular hematoma in resolution.

Case 3. A six-year-old male working Belgian Malinois, weighing 33 kg, had been treated for left forelimb lameness for four months previous to presentation. Intra-articular corticosteroids had given only a short improvement. The dog showed grade 3 (out of 4) lameness, slight reduction of the shoulder muscle, moderate pain in both flexion and extension of the shoulder, and the elbow did not extend jointly with shoulder flexion.

Radiographic findings of the left shoulder included signs of moderate osteoarthritis with osteophytes (range of 2–4 mm) on the caudal rim of the glenoid cavity, caudal humeral head, and smaller osteophytes (range of 1–2 mm) along the bicipital tendon groove. Mild signs of subchondral bone sclerosis were also evident.

Ultrasonography of the left scapula-humeral region revealed a severe and chronic grade 3 tenosynovitis of the biceps brachii tendon (Figure 2A), with moderate tendon hypotrophy. Moreover, an

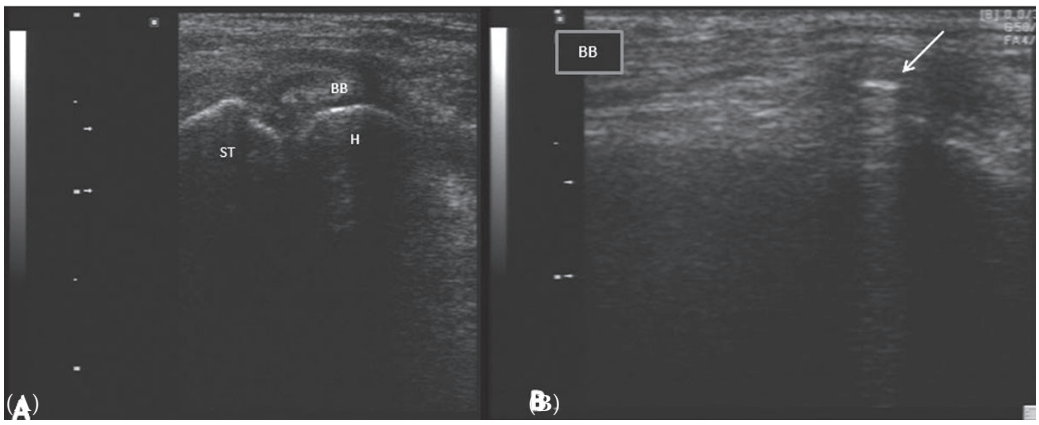

Figure 1. Six-year-old female Irish Red Setter dog. **A**: Longitudinal scan of left shoulder joint. Complete rupture of the biceps brachii (BB) tendon on its proximal part. A small bone fragment was easily recognised on the supraglenoid tubercle (ST); (H = humerus). **B**: 12-month follow-up. No inflammatory reactions, mineralised lesions or tendon disruption were observed around the T-staple (white arrow)

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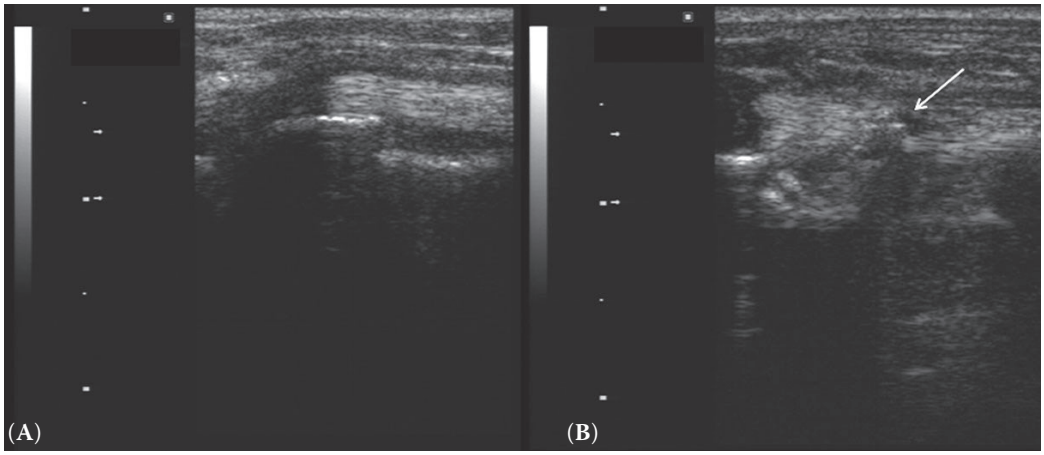

Figure 2. Six -year-old male Belgian Malinois dog. **A**: Longitudinal scan of the biceps brachii tendon along the bicipital groove. A grade 3 tenosynovitis of the biceps brachii tendon was observed. **B**: 30-day follow-up revealed a moderate inflammatory response around the T-staple (white arrow) and imperfect fibre alignment

irregular hyperechoic profile of the intertubercular groove consistent with osteophytes, was observed. The mean echogenicity of the tendon along the intertubercular groove was mildly reduced compared to that of the contralateral limb.

Surgical treatment. In brief, three types of shoulder diseases (partial and complete brachii biceps tendon rupture, and chronic tenosynovitis) were diagnosed. Each dog was surgically treated using the same tenodesis procedure.

A modified cranio-medial approach to the shoulder was performed (Piermattei and Johnson 2004). The superficial and deep pectoral muscles were exposed and their insertions were freed from the proximal border of the humerus. The extension synovial sheath of the joint capsule was incised only distally to the transverse humeral ligament. The latter was transected, and the biceps tendon was exposed. Traction on the bicipital tendon in the distal direction was applied and it was later cut as proximally as possible, without exposing the supraglenoid tubercle. The intertubercular groove was inspected and osteophytes were removed, when present. Furthermore, to identify the correct functional point of fixation, a mild traction was applied on the bicipital tendon in order to achieve a flexion of the elbow, as well as to allow its passive extension. The tendon was re-attached to the humerus just distally to the intertubercular groove using a metal T-staple, positioned and fixed in a caudolateral direction. The extremity of the tendon, resulting in an excess proximally to the staple, was removed at 5–6 mm from the staple.

All other muscular structures were repositioned and subcutaneous and cutaneous layers were sutured.

The metal surgical implant was constructed of AISI 316L stainless steel (Figure 3-inset).

Pre- and postoperative care. Perioperative analgesia was achieved through methadone (0.3 mg/kg intramuscularly) in premedication followed by fentanyl (5 mcg/kg/h intravenous) during surgery. After surgery, each dog received carprofen (2–4 mg/kg daily subcutaneous) for seven days and tramadol (2–5 mg/kg twice daily orally), if required for supplemental analgesia. The owners were instructed to limit physical activity and to allow walks on a leash for 30 days before leaving the dogs to resume normal levels of activity.

Follow-up and outcome monitoring. Follow-ups were carried out at 1, 2, 4 and 12 months after surgery in all three cases.

Clinical examination revealed an improvement of the clinical signs and the complete disappearance of pain and lameness at one month after surgery.

Radiographs were taken at the end of the surgery to verify the correct position of the staple in all dogs. Further radiographic exams were performed during the follow-up (1, 2, 4, and 12 months) which did not reveal significant changes of the shoulder image, nor implant migration (Figure 3).

Ultrasonographic follow-ups were performed in order to monitor the healing process and the inflammatory reaction next to the metal T-staple implant. All three clinical cases showed common features with respect to postoperative ultrasonographic healing, despite the different initial pa-

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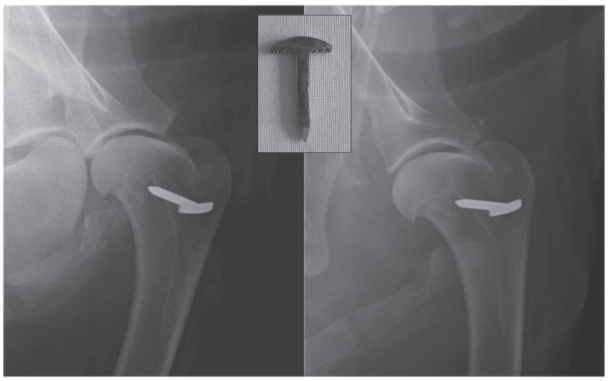

Figure 3. Radiographic images of the left shoulder of a six-year-old female Irish Red Setter taken immediately after surgery (left image) and one year following tenodesis (right image). Slight changes in osteoarthrosis are only just visible at this point in time. The T-staple is placed distally to the bicipital groove in the craniocaudal and medio-lateral direction. Inset: the stainless steel T-shaped staple; 17 mm in length, 10 mm in width and with a thickness of 2 mm

thologies. One month after tenodesis (Figure 2B), a mild-to-moderate hypoechoic inflammatory reaction was observed in the bicipital tendon at the site of fixation close to the staple. Moreover, an imperfect fibre alignment was observed in Case 3. During ultrasound follow-ups at two and four months after surgery, a correct tendon fibre alignment was observed in all three cases, with a mild anechoic pattern around the staple. At 12 months follow-up, no inflammatory reaction was seen at the T-staple site. Neither mineralised lesions nor tendon disruption were observed in any of the three clinical cases (Figure 1B).

Both imaging exams were also performed on the sound contralateral forelimb and each dog was its own control for pre-surgical and follow-up evaluations.

DISCUSSION

The three cases described in this report were affected by the most frequent bicipital lesions. Tenodesis was performed as the patients were working dogs, and the healing process after tenodesis was followed up, using x-ray and ultrasound examinations, for up to one year.

The signalment, age and weight reported in our three cases are consistent with the literature (Rivers et al. 1992; Kramer et al. 2001). Bergenhuyzen et al. (2010) described a lower mean age of 3.5 years but a wider range from six months to 10 years of age, and the dogs of that clinical communication were represented by medium-large breeds, mainly by Border Collies and Bernese Mountain dogs, but no information was reported about the weight of the animals (Bergenhuyzen et al. 2010). Previously, a case report concerning 15 dogs described wider weight and age ranges, 13–44 kg (mean 28.4 kg; median 29 ± 9.2 kg) and 1–15 years (mean 6.9 years; median 7 ± 3.8 years), respectively (Bruce et al. 2000).

The normal ultrasonographic anatomy of the canine biceps brachii tendon as well as ultrasonographic aspects of bicipital tendinitis and tenosynovitis have been widely described in dogs (Bruce et al. 2000; Kramer et al. 2001; Spinella et al. 2013). The benefits of ultrasonographic examination were proven by other authors whose data run counter to the initial results obtained by Rivers et al. (1992), who observed a low sensitivity of this technique. Ultrasonography provided immediate information on tendon integrity, lesion classification and assisted in treatment choice. Moreover, it allowed the monitoring of the healing process after injures or surgical procedures (Rivers et al. 1992; Kramer et al. 2001), providing information on tendon fibre reorganisation and alignment, as well as the recovery of normal mean echogenicity of the tendon structure.

In the present report, the efficacy of ultrasonography as well as its suitability for the diagnosis of complete or partial rupture of the biceps brachii tendon and tenosynovitis, as well as in monitoring the healing process and inflammatory reaction when the tendon fixation is achieved by a T-staple, is confirmed and verified. Our findings are consistent with the results reported by other authors, confirming that better results are obtained when a linear probe is used for tendon examination in dogs and horses (Long and Nyland 1999; Bruce et al. 2000; Kramer et al. 2001; Agut et al. 2009; Vilar et al. 2011; Spinella et al. 2013). Moreover, ultrasonographic findings confirmed the biological inactivity and biocompatibility of stainless steel AISI 316L, and revealed minimal tissue reaction of fibre tendon around it, with no chronic or degenerative lesions, up to 12 months after tenodesis (Navarro et al. 2008).

In the veterinary literature, viewpoints regarding biceps tenodesis versus tenotomy for surgical intervention have been conflicting, and the lack of

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papers comparing the long-term results of the two techniques did not enable one to be unequivocally considered better than the other.

The biceps tenotomy may be performed using arthrotomy, arthroscopy (Wall and Taylor 2002), or percutaneously (Venturini et al. 1998; Esterline et al. 2005). Excellent long-term results were reported by Bergenhuyzen (2010) who performed the shoulder arthroscopy in a standardised manner using craniolateral and caudolateral portals for a standard compartmental approach as Van Ryssen et al. described in 1993. Moreover, a cadaveric evaluation of arthroscopic tenotomy was performed to improve and give more information on this technique (Holsworth et al. 2002). The authors observed that the craniolateral camera port provided an optimised tendon visualisation, if a combined moderate shoulder and elbow flexion was applied. Moreover, tenotomy was easier to perform using a blade and could not be carried out with the shaver (Holsworth et al. 2002).

The biceps tenodesis can be carried out using arthroscopy or arthrotomy (open procedure). Cook stated that since the forelimb bears the majority of the weight in dogs, biceps tenodesis might be advantageous for this species, and he performed the procedure using arthroscopy (Cook et al. 2005). He used two kinds of devices, a cannulated interference screw in four dogs and a screw with tissue washer in two dogs, fixed into the bone of the most distal point in the intertubercular groove which was visible arthroscopically (Cook et al. 2005). Arthroscopic procedures performed on the shoulder have been widely documented (Van Ryssen et al. 1993; Martini et al. 2002), but only Cook's clinical study reported arthroscopic tenodesis (Cook et al. 2005). Excellent long-term results were described by open biceps tenodesis (Stobie et al. 1995), in contrast with the mixed results described in other papers (Bruce et al. 2000; Innes and Brown 2004).

Regarding biceps tenodesis, there are no evidence-based recommendations for the ideal level at which to cut and stabilise the tendon.

In the surgical technique described in the present paper, the exposure of the tendon was achieved with low invasiveness, without opening the joint capsule or exposing the supraglenoid tubercle, but only the synovial sheath just beyond the transverse humeral ligament. This procedure provided an easier approach to the tendon distally from its insertion on the supraglenoid tubercle in contrast with the open approach which involves incision of the joint capsule (Todoroff 1998; Denny and Butterworth 2000; Adamiak and Szalecki 2003; Piermattei and Johnson 2004). Unlike other described procedures, we did not approach the bicipital tendon using osteotomy of the greater tubercle (Stobie et al. 1995; Piermattei and Johnson 2004).

The arthroscopic approach and the mini-arthrotomy permit tenotomy and tenodesis (if done) close to the proximal insertion of the tendon that could involve an injured part of the tendon in the tenodesis. In the procedure described here a traction on the bicipital tendon in the distal direction was applied which was later cut as proximally as possible, without exposing the supraglenoid tubercle. The part of the tendon proximal to the site of tenodesis was removed to decrease the risk of inflammation.

Arthroscopically, shoulder inspection is excellent in all joint compartments (Van Ryssen et al. 1993; Martini et al. 2002), and the transection of the tendon is made after tenodesis (Cook et al. 2005). To perform the tenodesis using an open procedure it was our preference to cut the tendon before its fixation according to the techniques described in the literature (Piermattei and Flo 1997; Denny and Butterworth 2000; Adamiak and Szalecki 2003). The tendon was fixed with the elbow flexed to achieve the correct tension on the muscle in Cases 1 and 2 (positive in the tendon biceps test), with a complete extension of the elbow during the flexion of the shoulder.

Several methods of bicipital tenodesis have been previously described, e.g. suturing of the tendon to the periosteum, using a bone screw and spiked washer, giving a new attachment to the supraspinatus tendon, transporting the tendon through a hole drilled in the greater tubercle or using a ligament staple to reattach the tendon into the intertubercular groove (Piermattei and Flo 1997; Denny and Butterworth 2000).

The rationale for our approach of performing the tenodesis with a metal-T-staple was related to the idea that this kind of staple with a "T" shape pressing uniformly on the transected tendon would facilitate more rapid healing and prevent ischaemic injures, as was then observed during the ultrasonographic follow-ups.

Previously, Adamiak and Szalecki (2003) reported the surgical treatment of bicipital tenosynovitis with double tenodesis in order to achieve a safer tendon attachment to the bone. However, they

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described a tendon calcification, visualised after a radiological re-evaluation. In our study we did not observe any dystrophic calcification, both with radiography and ultrasonography exams; further, no major or minor complications such as infection, migration of implant, or seroma occurred.

Seroma, displacement or joint laxity, infection, pain and intermittent lameness can all be potential complications in both tenodesis and tenotomy procedures, but a detailed perusal of the literature indicates that most studies report beneficial outcomes. By contrast, in human medicine, a cosmetic "Popeye deformity" is frequently observed in patients treated with tenotomy (Gurnani et al. 2015). This is likely due to the different anatomical conformation of the canine biceps tendon.

A limitation of this report was the small number of patients examined. These studies should therefore be extended, and accompanied by a histological tendon evaluation, in order to create a more reliable clinical picture. However, to the authors' knowledge postoperative ultrasound assessment after tenodesis has not been reported until now. The ultrasound findings reported here suggest that the surgical procedure performed in the three dogs did not weaken the bicipital tendon and preserved elbow flexion and the functional muscle.

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