Case Report

Carpal arthrodesis using a minimally invasive approach and locking compression plates: Three cases

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Summary

Three horses with carpal instability due to comminuted second carpal bone fractures (Cases 1 and 3), fracture of the head of the second metacarpal bone (Case 1) or comminuted fractures of the fourth carpal bone, ulnar and intermediate carpal bones (Case 2) were treated by minimally invasive approach for partial (Cases 1 and 3) or pancarpal (Case 2) joint arthrodesis, using locking compression plates. The joint cartilage was removed by either an arthroscopic approach (middle carpal joint and antebrachio-carpal joint) or a percutaneous drilling technique (carpometacarpal joint). Two or 3 locking compression plates were contoured to the dorsolateral, dorsomedial and dorsoaxial aspects of the carpal joints using a custom-made tunnelling tool and a minimally invasive tunnelling technique, and the screws were positioned through stab incisions. All cases recovered well, were lame free at the walk, were able to trot and gallop and could be used for leisure and pasture activities (partial carpal arthrodesis) and breeding (pancarpal arthrodesis). Post-operative x-rays showed progressive joint fusion after 12 months (Case 1), 5 months (Case 2) and 10 months (Case 3). Case 2 with a pancarpal arthrodesis showed a mechanical lameness at the walk due to the inability to flex the carpus. Carpal flexion after carpometacarpal and middle carpal arthrodesis in Case 1 was calculated to be 42.6° and 44° in Case 3.

Introduction

Comminuted or displaced fractures of the carpal bones are not common in horses and are often associated with major carpal instability (Auer and Lischer 2012). If accurate anatomical reconstruction of the fractured bone is impossible, the only treatment to restore weightbearing and to prevent deformity, severe osteoarthritis or opposite forelimb laminitis is joint arthrodesis. Two types of carpal arthrodesis have been described (Barr 1994; Carpenter et al. 2008; Auer and Lischer 2012). If one of the 3 carpal joints (carpometacarpal [CMC], middle carpal [MC] joint or antebrachial carpal [ABC] joint) or 2 (CMC and MC) are involved then partial carpal arthrodesis is appropriate. For partial joint arthrodesis, the CMC joint alone, the MC and CMC joint together, and the ABC joint alone can be fused. Range of movement after partial carpal arthrodesis is limited to the non-used joint [e.g. after ABC joint arthrodesis the range of flexion depends on the range of flexion of the MC joint] (Tulloch et al. 2015). However, if both MC and ABC joints are affected, pancerpal arthrodesis is recommended with complete loss of joint movement (McIlwraith et al. 2015; Tulloch et al. 2015). In high motion joints such as the metacarpophalangeal or ABC joints, arthrodesis is essentially a salvage procedure, the aim being to allow comfortable locomotion at pasture or to save the animal for breeding purposes. According to Lewis (2001), the long-term prognosis for salvage was good (81%) but complications included implant failure and contralateral laminitis. The standard approach is a slightly curved incision over the dorsal aspect of the distal radius (in the case of a pancarpal arthrodesis or partial ABC joint arthrodesis), carpus and proximal metacarpus (Barr 1994; Carpenter et al. 2008; Auer and Lischer 2012). Carpenter et al. (2008) described use of one 16-hole and one 14-hole large fragment locking compression plates (LCPs) for pancerpal arthrodesis, with a single 40 cm long vertical skin incision made on the dorsal aspect of the limb. The main disadvantages of a large incision include the higher exposure to contamination and the difficulties for closure of the incision, especially over one or more voluminous osteosynthesis plates. Minimally invasive plate fixation, keeping the skin over the plate intact and making small incisions over the plate holes to allow screw insertion, was described by James and Richardson in 2006, who employed this minimally invasive technique in 22 cases of incomplete distal third metacarpal/metatarsal condylar fractures, and 6 fetlock and 4 pastern arthrodeses (James and Richardson 2006). Here, we report our experiences with a minimally invasive approach for partial and pancerpal arthrodesis, in which either 2 or 3 LCP were applied in 3 horses.

Case histories

Case 1

A 10-year-old Warmblood gelding was referred to the clinic with a radiographic diagnosis of an acute, displaced comminuted fracture of the second carpal bone (C2) and head of second metacarpal bone (MCII) of the right front limb of unknown cause. The horse was referred immediately after injury with a large Robert Jones full leg bandage and a caudally-applied splint.

Case 2

A 10-year-old Arabian mare was referred due to the sudden occurrence of severe left forelimb lameness during an endurance race. The referring veterinarian diagnosed multiple fractures of the proximal row of carpal bones based...
on radiographs, applied a Robert Jones full leg bandage with 2 full-length wooden splints on the lateral and caudal aspects to stabilise the limb, and administered 4.4 mg/kg bwt phenylbutazone i.v. prior to immediate referral.

Case 3
A 10-month-old French Standardbred colt was found lame on pasture, was diagnosed with a comminuted fractured C2 based on radiographs, and immediately referred with a Robert Jones full leg bandage with a palmar splint.

Clinical and radiographic findings

Case 1
The gelding had a severe lameness apparent at the walk and rested the limb on the tip of the hoof (grade 5/5 American Association of Equine Practitioners [AAEP; Swanson 1984]) with a moderately swollen medial aspect of the carpus that was painful to flexion. Lateromedial (LM), dorsopalmar (DP), dorsomedial-palmarolateral oblique (DMPLO) and dorsolateral-palmaromedial oblique (DLPMO) radiographic projections showed a displaced sagittal C2 fracture and an oblique, displaced articular fracture of proximal MCII. The medial fragment of C2 showed marked medial dislocation, with several small fragments and pinpoint mineral opacities in/around the fracture gap, and soft tissue swelling on the medial aspect of the carpus.

Case 2
The mare was nearly nonweightbearing on the left forelimb due to carpal instability that resulted in a valgus deviation of the limb at the carpus [grade 5/5 AAEP (Swanson 1984)]. Effusion and oedema of the soft carpal tissues was apparent and flexion of the carpus caused pain and obvious crepititation. Radiographs (DP, DLPMO and DMPLO) showed severe multiple, comminuted and displaced fractures of the ulnar, intermediate, and fourth carpal bones (C4) with carpus valgus, caused by collapse of the lateral aspect of MC and ABC joints. Numerous small fragments were visible on the lateral aspect of the carpus (Fig 1).

Case 3
The colt was lame at the walk, with an exaggerated head and neck nod (grade 4/5 AAEP [Swanson 1984]), flexion of the carpus elicited a pain response, and swelling was apparent on the lateral aspect. Radiographs (LM, DP, DMPLO and DLPMO) showed a comminuted markedly displaced fracture of the medial border of C2, and thickening of the periarticular soft tissues.

Surgical details

Case 1
After premedication with sodium penicillin (Penicilline G, Panpharma, Luitré, France, 22,000 iu/kg bwt. i.v.), gentamicin (Forticine, Vetoquinol, Lure, France, 6.6 mg/kg bwt. i.v.) and phenylbutazone (Phenylarthrite, Vetoquinol, Lure, France, 4.4 mg/kg bwt. i.v.) and sedation with acepromazine (Calmivet, Vetoquinol, Lure, France, 0.05 mg/kg bwt. i.v.) and detomidine (Detogesic, Zoëlis France SAS, Paris, France, 0.04 mg/kg bwt. i.v.) and morphine (Morphine Lavoisier; CDM Lavoisier, Paris, France, 1 mg/kg bwt. i.v.) the gelding was induced with ketamine (Ketamidor, Richter Pharma AG, Wels, Austria, 2.2 mg/kg bwt. i.v.) and diazepam (Valium; Roche SAS, Boulogne-Billancourt, France, 0.02 mg/kg bwt. i.v.) and positioned in left lateral recumbency. General anaesthesia was maintained with isoflurane (Isoflo, Zoëlis France SAS, Paris, France) in oxygen and air in a semiclosed ventilating system, combined with a detomidine constant rate infusion [0.04 mg/ kg bwt/h]. Aseptic preparation of the right front limb from the coronary band to the elbow, was done in preparation for a partial carpal arthrodesis of the MC and CMC joints. Arthroscopy was performed on the MC joint using a lateral approach and a medially-positioned instrument portal. The visible articular cartilage was removed with a manual curette for debridement of the medial aspect of the joint. Subsequently the position of the arthroscope and the curette were switched in the portal sites so the cartilage on the lateral aspect of the joint could be visualised and curetted. After debridement down to the subchondral bone, a cancellous bone graft (approximately 4 mL) was aseptically inserted.

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collected from the ileal wing and injected into the MC joint through the lateral and medial arthroscopy portals using 3 mL syringes with their tips cut off. The portals were then closed in a routine manner and the fluoroscope positioned in a lateromedial direction. Debridement of the CMC joint cartilage was achieved using a drilling technique through stab incisions. A 4.5 mm drill bit was inserted approximately 2.5 cm laterally, dorsolaterally and dorsomedially and the drilling was performed with a fanning technique (3 horizontal directions for each insertion point) under fluoroscopic guidance. A longitudinal 3-4 cm skin incision was made on the lateral aspect of the proximal third of the third metacarpal bone (MCIII), after which a custom-made tunnelling tool/plate-passer (James and Richardson 2006) was inserted under the skin (under fluoroscopic guidance) to create a subcutaneous tunnel in direct apposition to the periosteum. The tunnelling tool was pushed over the thin fibrous CMC joint capsule and under the thick joint capsule of the MC joint by pressing its tip against the distal aspect of the capsule, incising it through the skin and gliding the tool under the capsule and under the synovial membrane (Supplementary Item 1). This was performed to be able to place the plate close to the bone surface and create stability as the distance between the plate and the bone was reduced and therefore allowing to anchor the carpal bones with angled nonlocking cortical screws. A similar incision was made on the proximal aspect of the MC joint capsule to allow the tool to exit. A 7-hole narrow LCP plate was suitably contoured with radiographic control using a plate-bending press (Synthes). After verifying the appropriate placement by fluoroscopy and radiography, stab incisions were made through the most proximal and most distal holes of the plate after palpation of the depression of the plate hole. LCP drill guides were inserted and radiographic and fluoroscopic images were again obtained before drilling holes in the MCIII and intermediate carpal bone, and inserting the locking head screws (LHS) while pressing the plate firmly against the bone. A 4.5 mm cortical screw was placed in the intermediate carpal bone using an angle in order to avoid entering the articulation between the intermediate carpal bone and the third carpal bone. An LHS was placed in the third carpal bone, the remaining 3 distal holes were filled with 2 LHS and a 4.5 mm cortical screw inserted using stab incisions in the MCIII. This procedure was repeated on the medial side using a 7-hole broad LCP plate. The most proximal hole was filled with a LHS inserted in the radial carpal bone, the second proximal hole was a LHS inserted the third carpal bone and the third most proximal hole was filled with a 4.5 mm cortical screw inserted in the third carpal bone. Three LHS and one 4.5 mm cortical screw were anchored in the MCIII (Fig 2). The skin incisions were closed in a single layer using 1 USP monofilament polyamid (Ethilon). A full limb fibreglass cast was applied and a head and tail rope system used to assist recovery, which was uneventful. Anaesthesia time was 5 h and surgical time was 3.25 h.

Case 2
Premedication, sedation, induction and maintenance of general anaesthesia were similar to Case 1. The mare was placed in dorsal recumbency, with the limb attached to an electrical winch. This positioning allowed a good alignment of the limb in extension and radiographic control of the position of the limb and the plates was easy to achieve from all directions. General anaesthesia was maintained as described for Case 1. The limb was aseptically prepared and draped for a pancarpal arthrodesis. The MC and ABC joint were debrided using arthroscopy, the CMC joint was debrided with the drilling technique as described for Case 1. An arthroscopic motorised shaver device (Arthrex Shaver with Oval FlushCut 8 Flute, 5.5 mm, 13 cm, Ref AR 8550FOE) was used to facilitate articular cartilage debridement in the MC and ABC joint. Cancellous bone graft (approximately 6 mL) was collected from the sternum due to the position of the horse in dorsal recumbency. A technique described by Richardson et al. (1986) was used; briefly, a 7 cm incision was performed approximately 20 cm cranial to the xyphoid, the pectoral muscle was elevated and after removing the ventral cartilage of the underlying forth and fifth sternebrae, the cancellous bone was removed using a large curette and was injected into MC and ABC joint through the arthroscopy portals similar to Case 1. First, a 12-hole, 5.5 mm broad LCP plate was placed dorsally and medially and was stabilised with 4 LHS in the distal radius and 4 LHS anchored in the MCIII (Figs 3 and 4). Again the plate was placed under the MC and ABC joint capsule. The skin was closed using a combination of skin sutures (same as Case 1) and skin staples. Full limb fibreglass cast application and assisted recovery was as described for Case 1. Total anaesthesia time was 5 h and total surgery time 3.5 h.
Case 3
Premedication, sedation, induction and maintenance of general anaesthesia were as described for Case 1. The horse was placed in right lateral recumbency and prepared for partial arthrodesis of MC and CMC joints. Cartilage debridement of MC and CMC joints was achieved as in Case 2. Cancellous bone graft (approximately 4 mL) was collected from the ileal wing and inserted through the arthroscopy portals of the MC joint. Three LCP plates were applied using the same minimally invasive technique under fluoroscopic and radiographic control. The decision to place 3 plates instead of 2 was made to allow placement of more screws into both rows of the carpal bones in order to add stability to the construct (D. Richardson, personal communication, 2014). The plates were placed in a dorsolateral (6-hole, narrow 4.5 mm), dorsomedial (7-hole narrow 4.5 mm) and axial (6-hole broad 4.5 mm) position and stabilised using a combination of 5.0 LHS and 4.5 mm cortical screws. The proximal holes of all 3 plates were filled with LHS that anchored the proximal row of the carpal bones. The second most proximal holes of the dorsolateral and dorsomedial plate were filled with a 4.5 mm cortical screw that was angled proximally in order to anchor the proximal row of the carpal bones. The third, fourth most proximal and the most distal holes of the axial plate were filled with 4.5 mm cortical screw at slight angles in order to avoid contact with the LHS of the dorsolateral and dorsomedial plates (Fig 5). Skin closure, full limb fibreglass cast application and assisted recovery was as described for Case 1. Total anaesthesia time was 4.5 h and total surgery time 3 h.

Post-surgical management and outcome
Case 1
The gelding was fully weightbearing directly after surgery. Treatment with sodium penicillin (Penicilline G, 22,000 iu/kg b.wt. i.v.) and gentamicin (Forticine, 6.6 mg/kg b.wt. i.v.) was continued for 5 days. Phenylbutazone (Phenylarthrite, 2.2 mg/kg b.wt. i.v.) was given for 5 days and then dose was reduced to 1.1 mg/kg b.wt. i.v.) for another 10 days. The cast was removed standing 2 weeks after surgery and the skin sutures were removed at the same time. A sleeve (tube) cast from proximal antebrachium to distal metacarpus was applied for 4.5 weeks to maintain the carpus in an extended position. A Robert Jones bandage was applied for 2 more weeks. The horse was turned out on a large paddock 4 months after surgery. Radiographs taken 8 months after surgery showed thickening of the periarticular tissues.
(swelling), more pronounced dorsally. The LM projection showed bony fusion of the MC joint and new periosteal bone formation around the proximal part of the plates. Recurrent inflammation of the soft tissues on the dorsal aspect of the carpus resulted in episodes of lameness and a subclinical infection without drainage was suspected. It was decided to remove the plates under general anaesthesia. No signs of pus or liquid around the plates were found intraoperatively and the bacterial swab cultures of the plates were negative. Control radiographs immediately after plate removal showed ankylosis of the MC joint with periarticular bone (osteophytes) dorsally and medially and marked narrowing of the CMC joint space with periarticular bone formation (Fig 6). A full limb cast was applied for recovery and then replaced with a Robert Jones bandage that was left in place for 15 days until removal of the sutures. The horse was kept in the box for another 15 days and was then hand walked for one month. Then the horse had hydrotherapic rehabilitation with an oval water horse walker (System Voncini) during a period of 2.5 months. The first week, the horse was trained for 5 min/day, then the time of training was progressively increased to 20 min/day during the next 3 weeks. Twelve months after the initial surgical operation, examination by the authors revealed that the horse was not lame at the walk and showed a 2/5 AAEP lameness at the trot on a straight line. The owner was advised to use the horse as a leisure horse (ridden trot and light gallop). Today, 3 years after surgery, the owner reported that the horse is used as a leisure riding horse and a video of the horse showed that it was lame free at the walk and at the trot on a straight line. Carpal flexion is pain free and the maximal angle between the radius and the MCIII was calculated from a picture at 42.6° (Tulloch et al. 2015).

Case 2
The mare was fully weightbearing immediately after surgery. Antimicrobial treatment was continued for 10 days. Phenylbutazone (Phenylarthrite, 2.2 mg/kg bwt. i.v.) was given for 8 days. As for Case 1, the cast was removed 2 weeks after surgery and, at the same time, the skin sutures and staples were removed and a sleeve cast was applied. The sleeve cast was replaced by a modified Robert Jones full limb bandage 1.5 months after surgery (4 weeks after its application) and the mare was discharged from the clinic 9 weeks after surgery. The bandage was kept for another month and was changed once a week. A clinical examination 3 months after surgery revealed grade 2/5 AAEP lameness (Swanson 1984) at the walk and 3/5 at the trot with an abnormal gait due to the mechanical stiffness of the carpus. The radiographic evaluation at 5 months revealed ankylosis of the MC and ABC joints and thinning of the CMC joint, periarticular bone formation (osteophytes) of all 3 joints (more pronounced laterally) with mild thickening of the periarticular tissues (Fig 7). Nine months after surgery, the referring veterinarian reported, that the painful part of the lameness had disappeared and a 2/5 AAEP lameness at the trot remained due to the mechanical stiffness; the mare still showed an altered gait but was able to lie down and get up and could gallop in the paddock.

Case 3
As in Cases 1 and 2, the colt was comfortable in the cast after surgery and the antimicrobial treatment was continued for 5 days and anti-inflammatory medication were continued as in Case 2. Two weeks after surgery, the cast and sutures were removed standing and a sleeve cast was applied. The colt was discharged 15 days after surgery, the owner being
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used with caution, specifically for cartilage removal, to avoid inadvertent or excessive bone trimming leading to destabilisation of the bones. James and Richardson (2006) described arthroscopic debridement of the cartilage, in a case of metacarpophalangeal/metatarsophalangeal arthrodesis, as having the advantage of being thorough and accurate, but the disadvantage of requiring significantly more time. In our cases, arthroscopic debridement was completed quickly due to the arthroscopically noncomplex appearance of the MC and ABC joints. The arthroscope and the instruments were switched so that all visually apparent cartilage could be removed. We believe that, with the help of a motorised shaver tool, arthroscopic debridement for carpal arthrodesis can be completed within an acceptable time. An alternative minimally invasive debridement technique is to drill the cartilage with a 5.5 mm drill bit inserted through several stab incisions. James and Richardson (2006) reported using this technique for minimally invasive metacarpophalangeal/metatarsophalangeal and proximal interphalangeal joint arthrodesis. This procedure is quick but there is a possibility of incomplete cartilage removal. We believe that with the drilling technique there is a definite risk of incomplete cartilage removal, particularly in the MC and ABC joint, (due to the different small bones, articular steps and difficult fluoroscopic assessment). However, we did use drilling to debride the rigid CMC joint. We used a horizontal fanning technique through 3 incisions and this resulted in radiographically visible bony fusion in all 3 cases. Use of the drilling technique for treatment of CMC osteoarthritis is established and was evaluated on 12 client horses by Barber et al. (2009). It has also been used by Carpenter et al. (2006) for the CMC joint during a pancarpal arthrodesis procedure.

A minimally invasive approach was used to apply the plates. We made small skin incisions at the distal or proximal end of the plate and passed a custom-made tunnelling tool under the skin and under the joint capsule to create a subcapsular, intrasynovial path for the plate. We then passed the plate and applied screws through small skin incisions at the level of the plate holes. The minimally invasive principle of bone plate fixation was described by James and Richardson (2006) in a case series of 32 horses with lower limb injuries. A single plate was applied in all these cases, whereas 2 or 3 plates were minimally invasively applied in our cases. This added the difficulty of having to place the screws of one plate without them interfering with the screws of the other plate(s). In Cases 1 and 3, this step was facilitated by fluoroscopic image intensification, which also reduced the need for numerous radiographs. Fluoroscopy was not available for Case 2 and radiological exposure for the surgical team was probably higher than if an open approach had been used. One advantage of the minimally invasive approach is the ease of skin closure. Skin closure can be challenging with an open approach, where 2 or even 3 plates are placed, and can require tension-relieving sutures (Carpenter et al. 2008) or even relief incisions. These were not necessary in our cases and we were able to close all incisions with simple skin sutures and/or staples. This easier closure of the incision might help to reduce surgery time. However, the time taken to close the incisions was not recorded for any of the cases and would not be easy to compare with other reports due to the small number of cases published. The tension due to the subcutaneous plates was distributed over the many small incisions and this facilitated healing of the skin incisions. In all 3 cases, incisional healing was excellent, rapid, without dehiscence or secondary healing, and the final outcome was cosmetically appealing.

LCPs were applied in all our cases. These plates were initially described by Levine and Richardson (2007), in a case series of fracture repair and distal limb arthrodesis in 31 horses. They suggested the major advantage of such LCPs was the increased stability. The comfort of the horses after surgery in our report was good, and no loosened implants or screws were observed, confirming the stability of the constructs. Another advantage of LCPs cited by Levine and

Discussion

We report a minimally invasive technique for partial and pancarpal arthrodesis using LCP in 3 horses. In all 3 cases, complete debridement of the visually apparent cartilage in the MC (Cases 1, 2 and 3), and the ABC (Case 2), was achieved with curettes and motorised (shaver) burs, using a standard arthroscopy approach. Motorised burs should be used with caution, specifically for cartilage removal, to avoid inadvertent or excessive bone trimming leading to destabilisation of the bones. James and Richardson (2006) described arthroscopic debridement of the cartilage, in a case of metacarpophalangeal/metatarsophalangeal arthrodesis, as having the advantage of being thorough and accurate, but the disadvantage of requiring significantly more time. In our cases, arthroscopic debridement was completed quickly due to the arthroscopically noncomplex appearance of the MC and ABC joints. The arthroscope and the instruments were switched so that all visually apparent
Richardson (2007) was the reduced need for accurate anatomical plate contouring. Plate contouring, however, was considered necessary in our cases as the small carpal bones were fixed to the plate with 4.5 mm cortical screws in neutral or lag fashion. We used cortical screws in order to anchor as much of the small carpal bones as possible so as to increase stability. The application of cortical screws in a plate in a noncontact way could lead to screw loosening. Contouring the plates proved challenging, as the minimally invasive approach did not allow direct visualisation of the bone contours. Several radiographs or fluoroscopic image intensification were required for this step. The number of radiographic of fluoroscopic images is likely to be smaller in an open approach, pointing out a disadvantage of the minimal invasive approach. A third advantage of LCP mentioned by Levine and Richardson (2007) was that the threaded drill guides were helpful when drilling and applying the screws through small incisions. We add that these threaded drill guides made it possible to determine the position of the intended screw on radiographs and helped to hold the plate in place during insertion of the first LHS screw. We agree with Levine and Richardson’s comment that the use of self-tapping LHS screws eliminates the time-consuming step of tapping predrilled holes and would reduce surgery time. LCP and LHS implants have the disadvantage of being expensive, and our 3 cases of carpal arthrodesis each required 2 or 3 plates, leading to higher costs compared to the dynamic compression plate system.

Reported complications after carpal arthrodesis include supporting limb lameness, and infections of the incision and implant (Auer and Lischer 2012). The minimal invasive approach for carpal arthrodesis might have reduced the risk for infection in our cases. Minimally invasive plate fixation in horses reduces the tissue exposed to contamination and keeps the soft tissue envelope more intact than the conventional open approach (James and Richardson 2006). In their publication, James and Richardson compared 10 minimally invasive metacarpophalangeal/ metatarsophalangeal and proximal interphalangeal joint arthrodeses with 15 treated by conventional open approach. Only 4 of the 10 minimally invasive arthrodeses became infected, compared with 12 out of the 15 treated by open approach. There was no significant difference between these groups; however, a tendency is visible and the authors suggested that the minimally invasive arthrodesis technique may reduce morbidity and mortality of these procedures (James and Richardson 2006). For both partial and pancarpal arthrodesis, the incision required with the conventional approach is very long (up to 40 cm) (Carpenter et al, 2008) and therefore prone to postoperative infection. We report our experience of carpal arthrodesis using a minimal invasive approach in 3 cases and no infection occurred in this small sample group. However, we suspected a chronic infection in Case 1 and removed the plates 8 months after surgery. The bacteriological sample of the surgical site and plates were negative and an inflammatory irritation or instability might have been the cause of the intermittent discomfort. The horse was comfortable after the removal of the plates. We believe that using the minimal invasive approach for carpal arthrodesis reduces this risk, because of less tissue being exposed to contamination, less soft tissue trauma, tissue handling and tissue dehydration (James and Richardson 2006).

We found that the horses with the partial carpal arthrodesis (CMC and MC joints) had a nonpainful flexion with remaining angles of 42.6° and 44°, 3 years (Case 1) and 10 months (Case 3) after surgery, respectively. The remaining carpal flexion was calculated by Tulloch et al. (2015) in an ex vivo model to be 43 ± 7.6° after MC/CMC arthrodesis. The authors speculated that this would allow a horse to be used at a trot or slow canter and the outcome of our cases supports their statement, as both Cases 1 and 3 could trot and gallop without signs of lameness and Case 1 was used as a leisure riding horse. Pancarpal arthrodesis is known to be a salvage procedure. The mare in our study showed gait changes due to the stiffness of the limb but was able to trot and gallop and could fulfil the intended use as a breeding mare.

The minimally invasive LCP plate fixation technique seems to be well suited for partial and pancarpal joint arthrodesis. Disadvantages include the greater radiological exposure, due to the multiple control radiographs required to correctly apply the plates and screws. Surgery time is not necessarily shorter than with the standard open approach technique. The main advantages of the minimally invasive approach are easier closure and the lower exposure to contamination.

Authors’ declaration of interests
No conflicts of interest have been declared.

Ethical animal research
No experimental animals were included in the study.

Authorship
F. Rossignon performed all surgeries and contributed to the preparation of the manuscript. O. Brandenberger assisted in one surgery and wrote the manuscript. S. Bartke, T. Van Bergen and A. Vitte all assisted in one surgery. All authors have approved the final version of the manuscript.

Manufacturers’ addresses
1Ethicon, Issy Les Moulineaux, France.
2Arthrex, Lezennes, France.
3Kraft, Kraft Horse Walker, Frankenhardt-Hornhardt, Germany.

References


Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher’s website:

Supplementary Item 1: Minimal invasive plate application for carpal arthrodesis.