Medial radio-carpal arthrodesis in three cats with a 2.0 mm locking maxillofacial plate system

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Introduction

Radio-carpal arthrodesis is a salvage procedure used in cases of severe carpal damage, including luxations, degenerative changes of the carpal joint and associated structures, non-reparable comminuted articular fractures, joint destruction by septic or immune-mediated arthritis, irreparable soft tissue or bony trauma, and intractable infection (1–3). In cats, carpal damage is frequently the result of high-rise syndrome, which commonly leads to radial fractures and, less commonly, to carpal luxation with damage to the short ligaments and fibrocartilage (4, 5).

Radiocarpal arthrodesis relieves pain and restores stability of the limb, allowing weight-bearing (2). Different techniques of feline radiocarpal arthrodesis have been reported and include the use of internal fixation with 1.5/2.0 veterinary cuttable plates, crossed pins, 1.5/2.0 hybrid pancarpal arthrodesis plate, or crossed pins in combination with 1.5/2.0 veterinary cuttable plate or hybrid pancarpal arthrodesis plate (1, 6–9). Radiocarpal arthrodesis has also been performed with 1.5 mini-plates positioned dorsally, and with type II trans-articular external fixator alone and in combination with a dynamic compression plate (1, 6, 9). The use of medially-applied plates for radiocarpal arthrodesis in cats has thus far only been reported in a single case using a 1.5/2.0 hybrid plate (6).

A locking plate system (C2LS) was originally designed for human maxillofacial surgery and functions as an internal fixator, which achieves stability by locking of the screw head into the plate. Both experimental and clinical studies have shown that the locking mechanism of this system provides greater stability than standard non-locking plates (10–14). This may be of great advantage in cases in which extended healing periods are necessary or those associated with frequent implant-related complications, such as in radiocarpal arthrodesis (6, 15, 16–20). Plates available with the C2LS are in four thickness sizes: small (1.0 mm), medium (1.3 mm), large (1.5 mm), and extra-large (2.0 mm). The distance between the screw holes increases with increasing plate size (5 mm in small, 6.5 mm in medium, and 8 mm in large and extra-large plates). The 2.0 mm screws can be applied in all plate sizes as either locking or non-locking screws. The plates are titanium and screws are titanium alloy and self-tapping. Although use of the C2LS has been reported in a variety of applications in small animal orthopaedics in recent years, no previous publications report its use for medial plating in radiocarpal arthrodesis in cats (21–23).

The purpose of this report is to describe the use and outcome of C2LS in medial radio-carpal arthrodesis in three cats. We hypothesized that the system would be adequate regarding practicability, stability and overall outcome.

Case description

Medical records of three domestic short-haired cats admitted to the Clinic for Small Animal Surgery, Vetsuisse Faculty, University of Zurich, with uni- or bilateral carpal injuries were reviewed (Table 1). In all cases, carpal damage was due to high-rise syndrome and radiocarpal arthrodesis was considered appropriate.

Cat 1 was presented with a distal radial articular comminuted fracture (Fig. 1A).
Preoperative treatment consisted of immobilization with a splint and administration of analgesic drugs (buprenorphine\textsuperscript{b} 7 mg/kg IV every 4 to 6 hours). The basic surgical technique performed for radiocarpal arthrodesis was the same in all three cats.

Surgery was performed with the cat positioned in lateral recumbency with the affected limb lowermost. The iliac crest on the contralateral side was clipped and prepared for bone graft harvesting. Following administration of perioperative antibiotics (cephalexin\textsuperscript{c} 22 mg/kg IV), a dorso-medial approach to the carpus was performed with a skin incision starting at the distal third of the radius and extending to the distal third of the second metacarpal bone (MC2). The tendon of the abductor pollicis longus muscle was transected at its insertion on the proximal aspect of the first metacarpal bone (MC1), and the MC1 was amputated to provide space for plating (24). The superficial fascia was incised and the medial aspect of the bone was exposed by blunt dissection. The carpal joint capsule and the short carpal ligaments were incised to access the antebrachiocarpal, intercarpal, middle carpal and carpometacarpal joints. A burr drill was used to remove the articu-

### Table 1
Summary of findings, treatment and complications of the three cases.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Body weight (kg)</th>
<th>Side</th>
<th>Description of injury</th>
<th>Comments / Complications</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat 1</td>
<td>2</td>
<td>Left</td>
<td>Comminuted articular fracture of the distal radial epiphysis (Fig. 1A).</td>
<td>Complete radiocarpal joint fusion eight weeks after surgery and plate removal after six months without any signs of complications.</td>
<td>At six months</td>
</tr>
<tr>
<td>Cat 2</td>
<td>4.3</td>
<td>Left</td>
<td>Hyperextension injury with palmar subluxation of the radial carpal bone (Fig. 2A).</td>
<td>Complete radiocarpal joint fusion without complications (Fig. 2C).</td>
<td>At four years</td>
</tr>
<tr>
<td>Cat 3</td>
<td>9</td>
<td>Left</td>
<td>Hyperextension injury with palmaromedial luxation of the radial carpal bone (Fig. 3A).</td>
<td>Incomplete fusion of the radiocarpal joint at two year check without clinical symptoms (Fig. 3C). Breakage of the plate 4.5 years postoperatively (Fig. 3D). Placement of a Kirschner wire through the radial carpal bone into the ulnar carpal bone. Medial collateral ligament replacement. Healing uneventfully.</td>
<td>At 4.5 years</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Temgesic\textsuperscript{a}: ESSEX Chemie AG, Luzern, Switzerland

\textsuperscript{b} Kefzol\textsuperscript{b}: TEVA Pharma AG, Aesch, Switzerland

**Fig. 1** A) Dorso-palmar and mediolateral radiographs of the left carpus of Cat 1 showing a comminuted articular fracture of the distal radial epiphysis with cranial displacement. There is an increased distance between the radius and ulna consistent with luxation. B) Mediolateral and dorso-palmar postoperative radiographs after radiocarpal arthrodesis in Cat 1 showing good alignment of the radius, carpus and metatarsus. C) Radiographic follow-up examination eight weeks after radio-carpal arthrodesis in Cat 1. The joint spaces of the radiocarpal, middle carpal, carpometacarpal and intercarpal joints cannot be identified, consistent with complete carpal fusion. D) Radiographic follow-up examination six months after radiocarpal arthrodesis in Cat 1. The implants are removed after complete carpal joint fusion.
lar cartilage from the carpal joint surfaces until subchondral bone was exposed and osteostixis was performed (24, 25). Cooling with sterile saline (0.9% NaCl) solution was performed to prevent thermal necrosis. Corticocancellous bone harvested from the iliac wing was packed into the joint spaces.

An eight-hole (large) C2LS plate was contoured to achieve 10 to 12 degrees of carpal extension and positioned on the medial surface of the carpus (25). The plate was first fixed with two screws to the radius, followed by one screw applied to the distal carpal bones, and one to the most distal aspect of MC2. Intermediate screws were then placed with two further screws in the radius and two purchasing MC3 and MC4 in the proximal metacarpus (Fig. 1B). All screws were 2.0 mm locking screws. The wound was closed in layers. Orthogonal postoperative radiographs were taken and a splint was placed on the caudopalmar side of the affected limb. The splint was changed weekly and maintained until radiographic evidence of fusion was apparent, approximately six weeks after surgery.

Fusion of the arthrodesis was evident in this case eight weeks after surgery (Fig. 1C). The splint was maintained for six weeks and the plate was removed six months after surgery at the request of the owner. At this time, there were not any signs of plate-related discomfort (Fig. 1D).

Cat 2 was presented with a palmar luxation of the radial carpal bone (Fig. 2A) with multiple small bony fragments identified at the palmar aspect of the carpal joint (Fig. 2B). The surgical technique used was similar to that described for Cat 1. A private practitioner removed the splint one week after surgery, confusing the radiographic appearance of the bone graft with a healed arthrodesis. Despite this, the arthrodesis healed uneventfully (Fig. 2C).

Cat 3 was presented with bilateral carpal trauma. The right carpus had a palmar luxation of the radial carpal bone. The bone was reduced and a Kirschner wire was driven through the radial carpal bone into the ulnar carpal bone. A medial collateral ligament replacement was performed using a nonabsorbable braided polyester suture anchored between the Kirschner wire and a 1.5 mm cortical screw in the radial styloid process (26). Radiographs of the left carpus revealed a palmaro-medial luxation of the radial carpal bone (Fig. 3A) and clinical evidence of palmar instability after reduction of the antebrachiocarpal luxation. Radiocarpal arthrodesis was therefore performed on the left carpus. The surgical technique used was similar to that described for Cat 1. However, the most proximal radial screw was removed because the drill hole was paracortical (Fig. 3B). In addition, the corticocancellous bone graft was obtained from the proximal humerus of the contralateral side instead of the iliac wing. The splint was removed six weeks after surgery in this cat. Radiographs taken at this time and nine weeks after surgery revealed incomplete mineralisation of the radio-carpal joint. At this time, the owner was satisfied with limb function and declined further surgical intervention. Further radiographs taken one and two years postoperatively also revealed incomplete fusion (Fig. 3C) but no clinical signs of complications were detected. Four and a half years after surgery, the cat presented with mild lameness of the left front limb. At this time, radiographs revealed breakage of the plate at the level of the incompletely fused radio-carpal joint (Fig. 3D). The owner declined further surgical treatment because of concomitant health problems and because the joint was almost completely ankylosed at this time.

**Discussion**

This report is the first case series describing and evaluating radiocarpal arthrodesis in cats using medially-applied C2LS plates. Long-term follow-up assessments (6 months to 4.5 years) revealed excellent results in two cases but incomplete fusion, followed by late plate breakage in the third...
the drilled hole was in a paracortical position. Bones and metatarsal bones. The most proximal screw was removed because the antebrachial cortex but good alignment of the radius, ulna, carpal bones and metatarsal bones. The most proximal screw was removed because the drilled hole was in a paracortical position. C) Follow-up radiographs in Cat 3 taken two years after radio-carpal arthrodesis. The plate and screws are in the same position as in the initial follow-up examination. Note the reduced opacity of the distal radius, ulna and carpal bones suggesting stress protection. The antebrachial cortex is not fused while the middle carpal, intercarpal and carpometacarpal joint spaces present ill-defined contours consistent with partial fusion. D) Follow-up radiographs in Cat 3 taken 4.5 years after surgery. The plate is broken at the level of the antebrachial cortex, which appears incompletely fused.

Fig. 3 A) Dorso-palmar and mediolateral radiographs of the left carpus in Cat 3, showing antebrachial cortex luxation and caudomedial displacement of the radial cortex bone. Note the widening and uneven antebrachial cortex space. B) Mediolateral and dorso-palmar postoperative radiographs after radio-carpal arthrodesis in Cat 3. There is a persistent mild widening of the antebrachial cortex joint but good alignment of the radius, ulna, carpal bones and metatarsal bones. The most proximal screw was removed because the drilled hole was in a paracortical position. C) Follow-up radiographs in Cat 3 taken two years after radio-carpal arthrodesis. The plate and screws are in the same position as in the initial follow-up examination. Note the reduced opacity of the distal radius, ulna and carpal bones suggesting stress protection. The antebrachial cortex is not fused while the middle carpal, intercarpal and carpometacarpal joint spaces present ill-defined contours consistent with partial fusion. D) Follow-up radiographs in Cat 3 taken 4.5 years after surgery. The plate is broken at the level of the antebrachial cortex, which appears incompletely fused.

Medial application of the plate provides an increased moment of inertia, making it more resistant than other described techniques to the cranial bending forces present after rupture of the plantar structures. Furthermore, correct anatomical reduction and medial application of the plate provides dynamic compression during the stance phase of the gait. To minimise the risk of mediolateral bending of the implant, care was taken during surgery to correctly reduce the disarranged carpal bones.

However, one potential disadvantage of the C2LS is that compression between contact surfaces of the bones is not applied. This was evident on radiographs in Cat 3, which revealed gaps between bones in the radio-carpal joint and incomplete fusion, leading to plate breakage 4.5 years after surgery. Other possible reasons for incomplete arthrodesis fusion in this case include incomplete cartilage removal or high fat content and insufficient autogenous cancellous bone obtained from the proximal humerus in this nine-year-old cat. Graft harvesting from another site, in particular from the iliac wing, or allogenic cancellous bone grafting should therefore be considered in older cats if there is any doubt as to the amount or quality of the autograft. Despite plate breakage in this case, the plate remained intact for several years with an incompletely fused arthrodesis, suggesting good resistance to cyclic failure.

The stability of the construct was augmented using coaptation splints for six weeks. However, the splint was prematurely removed one week after surgery in Cat 2. From this time on, weight-bearing forces were resisted only by the C2LS plate until fusion occurred. In this case, arthrodesis occurred uneventfully (Fig. 2C). In early reports, splinting until fusion was complete was strongly recommended in cats. However, in other reports, complications were not associated with a decreased functional outcome when augmentation was not used or was prematurely removed. Moreover, C2LS plates are more stable than non-locking plates and external augmentation may not be necessary (10–14). More cases are needed to corroborate this hypothesis.

To the authors’ knowledge, only one case of a medially-applied plate for carpal arthrodesis in a cat has been reported. In that case, a 1.5/2.0 hybrid pancarpal arthrodesis plate was used, and no detailed description of the technique was provided. As no previous reports describe outcome with the use of locking plates, comparison with the results of the cases reported herein is not possible.

Plate loosening and metacarpal bone fractures are reported complications of pancarpal arthrodesis in cats. To reduce the risk of fracture, it has been previously recommended that cortex screws not exceed 40% of the diameter of the bone. Based on a study in which the diameter of the MC3 in fifteen cats was found to be between 3.15 mm and 4.13 mm, the 2.0 mm cortex screws of the C2LS occupy between 48.4% and 63.5% of the bone and therefore do not comply with this recommendation. Despite this fact that the screws exceeded 40% of the diameter of the bone, plate loosening and metacarpal bone fractures were not observed in any of the cats in the present report. The risk of metacarpal fracture may have been partially lessened by inserting screws through more than one metacarpal bone in order to distribute forces across more bones. In addition, long plates were used in order to position some screws in the distal metaphysis where the bone is wider, which may also contribute to decreased fracture risk by increasing the bone-to-screw diameter ratio. Indeed, Whitelock and others reported a reduced
risk of metacarpal bone fractures after dorsal plating for pancarpal arthrodesis in dogs when the plate extended over more than 50% of the third metacarpal bone (20). However, screws were quite difficult to apply and special care was taken to ensure correct placement of screws, mainly in the diaphysis of the metacarpal bones. Screws were not placed in the ulna. Pancarpal arthrodesis causes functional deficits and gait disturbances due to restriction of pronation and supination in the cat, and involvement of the ulna would further limit movement (2).

Insertion of screws perpendicular to the C2LS may not always be possible, depending on the individual anatomical situation, the kind of injury and because of the relatively large distance between the holes of this plate. If a screw is not inserted perpendicular to the plate, it may not lock properly. Although this was the case for some of the screws in the cases reported herein, no evidence of screw loosening was observed. To the authors’ knowledge, the locking function in angulated screws has not been investigated with C2LS plates although the manufacturer has indicated that 10 degrees of screw angulation is tolerated by the locking mechanism (personal communication).

The removal of the first metacarpal bone simplified the positioning of the plate on the medial aspect of the carpal joint in our three cats. Contouring of the plates was facilitated by the reconstruction plate design of the system.

No problems were evident in wound closure, but careful preparation of the skin before suturing is important to reduce suturing tension and to minimise the risk of suturing dehiscence.

In comparison to other implants, the implant costs for the C2LS system are high (1, 6–9). Although not evaluated in this report, the ease of application and the inherent stability of the system could balance its increased initial cost.

Conclusion

Radiocarpal arthrodesis performed with a C2LS plate on the medial aspect of the carpal joint represents an alternative treatment in cases of severe carpal damage in cats requiring arthrodesis. With amputation of the first metacarpal bone, the positioning of the plate is a relatively easy procedure in comparison to other techniques. The large distance between the holes of the plate and the relatively large screw size makes it sometimes difficult to position the screws in an appropriate position.

Conflict of interest

None declared.

References