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Novel Interlocking Nail Explantation Utilizing Custom-Made Jig and Cortical Bone Windowing Technique in a Dog

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Abstract

A 4-year-old, female, neutered, Greyhound cross presented to the Animal Referral Hospital, Canberra, for assessment and surgical correction of a proximally exposed interlocking nail within the left tibia, which was placed 20 months earlier. Removal included the use of a custom-made jig and cortical windowing technique. This method of extraction worked to combine preexisting knowledge from within the human medical field, specifically total hip arthroplasty procedures, while employing a novel extraction tool. At the time of publication, to the best of the authors' knowledge, no similar methods had been described yet.

Keywords

- corrective surgery
- fracture management
- fracture repair
- fracture fixation
- implants

Introduction

Interlocking nails (ILN) have earned a predominant place in the surgical veterinary practitioner's arsenal of internal fixation methods for long-bone fracture repair. First introduced by Gerhard Kuntscher in the 1930s as "elastic nailing," and later adapted for the veterinary context by Johnson and Huckstep in 1986, ILN offered significant advantages over more traditional bone plates in long-bone fracture repair.[1,2] These included greater fatigue failure thresholds, increased resistance to bending forces, increased stability against compression and torsion forces, and reduced risk of bone–nail construct failure due to screw pullout.[3]

ILN all consist of three major features: a solid intramedullary rod with proximal and distal transverse cannulations, locking screws or partially threaded bolts to engage both the nail and cis-/transcortices, and finally a distal trocar to enable insertion into the bone. Today some systems also include an hourglass profile, designed to minimize medullary blood supply trauma and endosteal iatrogenic damage, and to eliminate the need for medullary cavity reaming, while increasing construct compliance.[4]

ILN may also require explantation, with various reasons including implant failure, overlying long-bone breakage, articular dyskinesia, or even peri-implant infections.[5,6] Explantation can often prove quite technically challenging due to implant deformation or on-growth of new bone.[7,8] Several open and closed techniques have been described in both human and veterinary literature, including the use of interference fit guidewires, passing of hooks through the nail outlets, press fitting extractors or t-reamers throughout the central canals, capturing the nail externally, and simple removal through nonunion or surgically created holes.[6,8–10]

This case report describes a novel technique of I-Loc 6 mm (BioMedtrix, Whippany, New Jersey) ILN system extraction, specifically where proximal thread/extender failure has occurred, involving the employment of a custom-made extraction jig and creation of a cortical bone window through the mid-tibial diaphysis.

Case Report

Clinical History

A 4-year-old, female, neutered, Greyhound cross, originally presented to the Animal Referral Hospital, Canberra, for assessment of acute onset, left hindlimb lameness, suspected to involve a tibial fracture. Radiographs confirmed a closed, moderately displaced, short-oblique fracture of the distal

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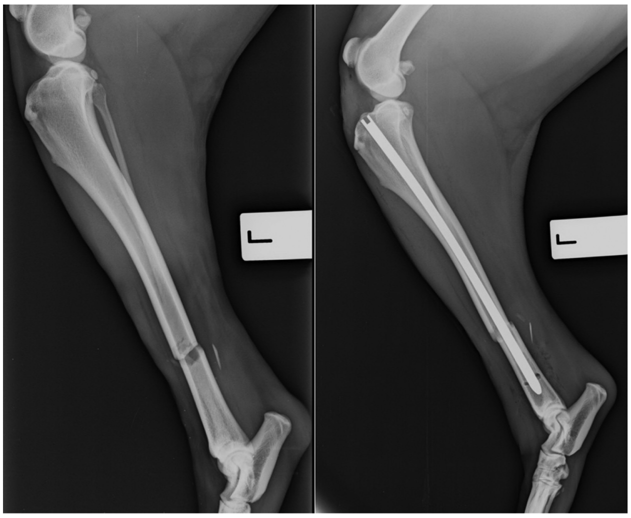

Fig. 1 Left mediolateral images of the preoperative fractured tibia (*left*), and immediately postoperative following initial distal bolt removal (*right*).

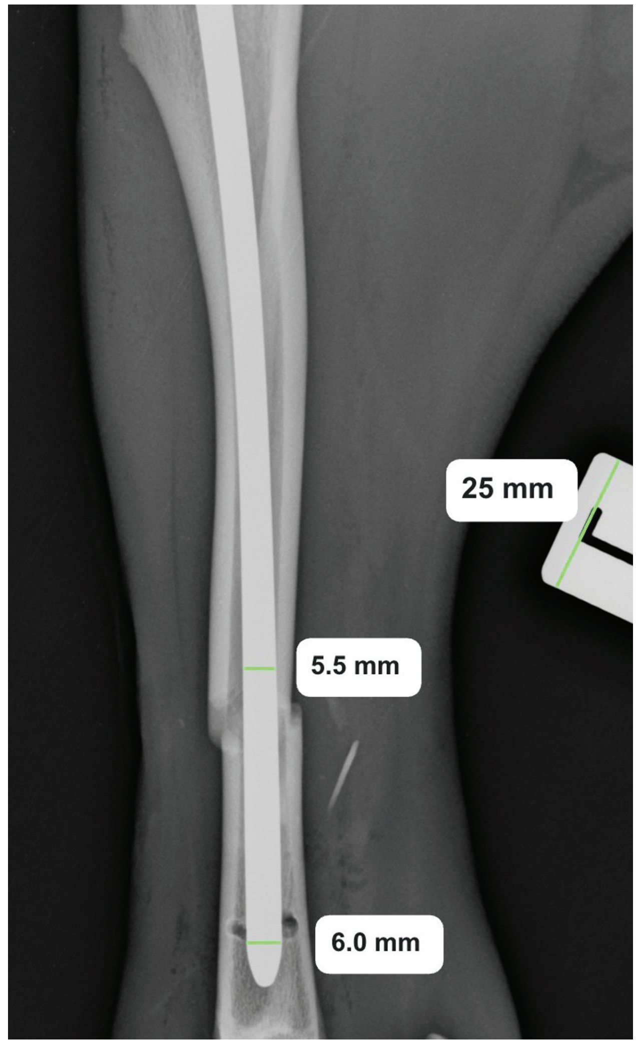

Fig. 2 Left mediolateral postoperative image directly following distal bolt explantation, demonstrating the hourglass intermedullary rod design.

third of the left tibia (►**Fig. 1**). Fracture repair was elected by the owner, involving placement of a 6 mm × 195 mm "I-Loc" nail system. Postoperative radiographs showed adequate placement, reduction, and bolt engagement with the nail. Additionally, postoperative rechecks showed an adequate return to function with no associated complications.

At approximately 21 months postoperatively the patient represented for assessment of a 6-month progressive lameness, with acutely associated medial distal bolt exposure. Note the patient had been seen by their referring veterinarian and placed on an extended course of antibiotics (i.e., amoxicillin/clavulanic acid). Radiographs revealed adequate callus formation at the fracture level, although distinct radiolucency and reduced density of the region of the distal tibia could be observed. This was suspected to be bone lysis associated with infection. As such, both distal bolts were surgically removed (►**Fig. 1**) and sent alongside tissue samples for culture and sensitivity. Culture and sensitivity reported a light growth of *Serratia marcescens*. It was assumed that this species was a contaminant and that the previously dispensed antibiotics had been suppressing the causative agent of the associated bone lysis. The patient was again discharged, with no concerns identified at rechecks.

At approximately 28 months postoperatively (8 months following re-presentation), the patient presented again, this time for suspected infection, with no lameness or discomfort evident. Upon physical examination, a small draining tract sinus was identified from the distal aspect of the bolt-removal incision site. It was presumed that a returning infection had occurred, due to an implant-associated infection, and complete apparatus removal was recommended.

Surgical removal of the ILN was elected by the owner. This involved removal of the remaining proximal bolts and intermedullary rod. Proximal bolts were removed with little resistance. Removal of the intermedullary rod proved more challenging, first requiring bone exposure of the proximal threads, achieved through mild rongeur gouging of the covering bone. This allowed placement of the ILN extender, and marked retrograde traction to be employed, providing approximately 35 mm of movement of the intermedullary rod. It became apparent that no further retrograde movement could occur, following complete stripping of the proximal thread, thereby not allowing further extender engagement to the intermedullary rod. At the time, this was assumed to be due to the hourglass design/shape of the intermedullary rod preventing retrograde movement as it was pulled through the narrowing tibial diaphysis, and the newly formed endosteal callous (►**Fig. 2**). The decision was made to conclude surgery and develop a new surgical plan with other board-certified surgeons. Explantation of the intermedullary rod was still indicated, due to the suspected persistent implant-associated infection.

Surgical Planning

Surgical planning involved the consideration of two key objectives: (1) requirement to employ retrograde traction to the intermedullary rod, without the use of standard proximal thread engagement systems, and (2) permit

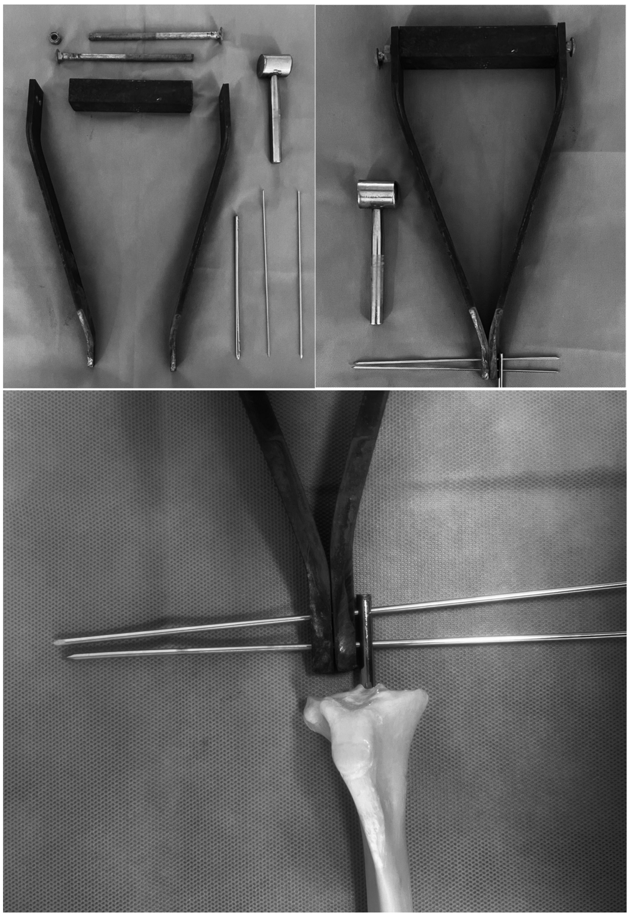

Fig. 3 Individual components of (*upper left*), assembled (*upper right*), and demonstrated intraoperative use (*lower*) of the custom-made extraction jig on a tibial bone model.

retrograde removal of the intermedullary rod given the hourglass shape and endosteal callous formation.

These objectives were discussed and identified to be fulfilled, first, by the employment of a custom-made jig to engage the proximal bolt holes, thereby allowing retrograde traction, and, second, by a cortical bone windowing technique, allowing passage of the hourglass-shaped rod.

The custom-made jig consisted of two flat 7 mm × 38 mm metal bars, shaped around a central 34 mm × 34 mm box-steel length, into a "handle shape." The base of the jig was held together by two bolts and nuts. Two holes at the apex of the jig allowed the engagement of Kirschner's wires, which could be fed through the existing bolt holes of the proximal rod. This enabled the jig to act as a handle, much like that of the ILN extender, allowing retrograde traction to be applied (►**Fig. 3**).

Surgical Treatment

The patient was again moved to surgery. The two proximal rod bolt holes were identified, and two large-diameter Kirschner's wires fed through, also engaging the jig. This allowed retrograde traction to be applied, also resulting in a further 10-mm movement before no further movement occurred. At the time, this was postulated to be due to the increased traction applied from the jig's size and weight.

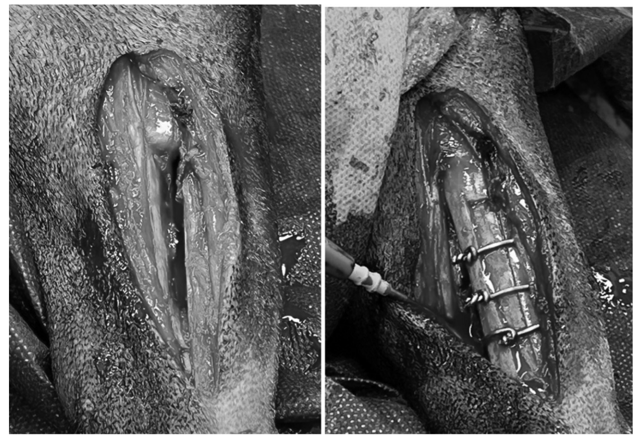

Fig. 4 Mid-diaphyseal tibial rectangular cortical bone window (*left*) and replaced/secured with cerclage wires (*right*).

The approximate location of the hourglass flange was estimated intraoperatively, and a sagittal saw was used to cut a rectangular cortical bone window out of the mid-tibial diaphysis (►**Fig. 4**). Note the long side of the window perpendicular to the long axis of the diaphysis. Care was taken to ensure the window borders were slanted inward and the total window width did not exceed one-third the circumference of the tibia. Complete retrograde removal of the intermedullary rod was then achieved.

Following explantation, the newly created tibial cortical window was secured with three encircling 16-gauge cerclage wire bands at evenly spaced intervals (►**Figs. 4** and **5**). Fascial, subcutaneous, and dermal tissue planes were closed as standard procedure. No additional external coaptation was employed.

Postoperative Management

Postoperative management included the development a patient-specific rehabilitation plan. This centered around a

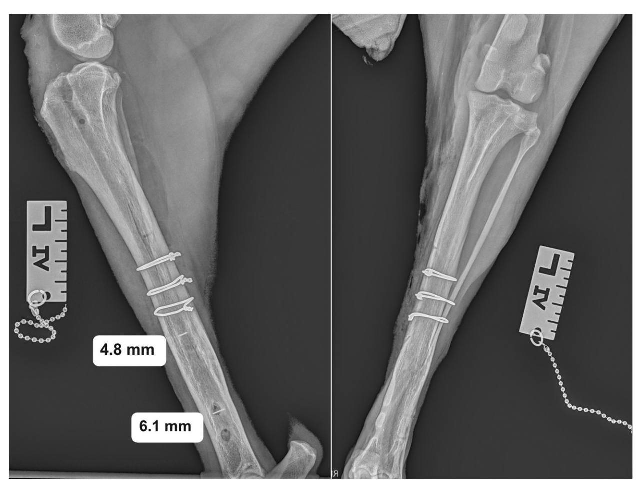

Fig. 5 Left mediolateral and caudocranial radiographs directly after complete apparatus explantation (28 months postoperatively since apparatus implantation), noting the reduced medullary width (due to endosteal callous formation), and thereby necessity for cortical window application.

Fig. 6 Left mediolateral and caudocranial radiographs approximately 6 weeks following complete apparatus explantation (34 months postoperatively since apparatus implantation).

specific and controlled, gradual reintroduction exercise plan, for example, short 5-minute, controlled, on-leash walks, up to four times per day for the first 2 weeks, followed by short incremental biweekly increases in walking time. Additionally, guidelines around feeding, weight management, and physiotherapy were given to the owner. Structured rechecks included an initial 2-week follow-up, and final 6-week radiographic check (►**Fig. 6**). Additional unstructured rechecks were offered as desired by the owner.

Outcome

The owner reported no clinical abnormalities or concerns at each of these postoperative rechecks. Similarly, after adequate radiographic (►**Fig. 6**) and clinical follow-up, no further issues were identified. Both veterinary and owner assessment considered the procedure a clinical success, with excellent return to normal patient function.

Discussion

This novel method of ILN extraction may present an effective method of removing challenging intermedullary rods, specifically in scenarios where the proximal thread has stripped and/or rod extraction cannot occur due to flanged design or large endosteal callous formation.

Proximal extender extraction device failure is known to occur for a variety of reasons, including stripping of the proximal threads (as seen in this case) or entrapment of impacted screws, introducers, taps, or extractors.[11] Due to the engagement method of the extender to the intermedullary rod through a bolt-and-thread engagement system, any thread stripping will prevent engagement of the extender and thereby application of adequate retrograde traction. As discussed, this system did not rely on these threads, rather utilizing the preexisting proximal bolt holes to facilitate retrograde traction to be applied to the rod. A major consideration for this jig is that not all scenarios will allow adequate exposure of the proximal bolt holes, and as such application of the jig may be limited.

The cortical windowing technique was first described in the human medical field, specifically for the removal of broken femoral stems in total hip arthroplasty procedures.[12] Park and colleagues[13] set out to further understand this technique, including commonly associated intraoperative and postoperative complications across 448 cases, from seven different studies (including their own). Complications observed included superficial and deep infections, associated nerve damage, and both intraoperative femoral and osteotomy fractures. In their own study, intraoperative femoral fractures at the cortical windowing site were observed in 2/56 cases, a relatively low percentage of cases (3.6%). Since then, the technique has also been applied to the veterinary field, specifically in the removal of cemented total hip stem protheses.[14,15]

Degórska and colleagues[15] originally described the windowing technique in a 2-year-old, male Golden Retriever canine that presented for routine 8-week postoperative cemented total hip replacement radiographs. At this point, lateral and ventrodorsal radiographs revealed a prominent midshaft prosthesis stem fracture. As such, the decision was made to explant and replace the prosthesis. A rectangular cortical section of bone (window) was removed from the lateral femur using an osteotome. This allowed further access to the implant fracture site and the associated cement, allowing adequate removal. Care was taken to ensure the edges of the bone were slanted to prevent collapse upon repositioning of the fragment and that the total length of the femoral window was one-third the circumference of the femur.

In much the same way as the approach outlined by Degórska and colleagues,[15] the cortical tibial window technique described in this article relied on the same underling principles. These included no greater than one-third of the tibial circumference being included in the tibial window, so as to not destabilize the tibia; a rectangular window approach over the site of estimated greatest resistance, in this case suspected to be due to the hourglass shape and endosteal callous formation rather than underlying cement; and the application of slanted cortical window edges to prevent excessive collapse upon replacement. Note that ►**Fig. 5** demonstrates the decreased medullary width at the fracture site (due to endosteal callous formation) and the necessity for the application of the cortical bone window.

The decision to secure the cortical bone window fragment with three encircling cerclage wire bands rather than cortical bone screws (placed in a lag fashion) was made intraoperatively. To stabilize a fracture (traumatic or iatrogenic), the repair method must generate adequate interfragmentary compression and prevent movement during normal physiological loading. Furthermore, fractures specifically amenable to cerclage wire repair must be reducible and have a fracture line at least twice the length of the diaphyseal diameter at the fracture level.[16] Additionally, the cortical window was intraoperatively determined to have only involved approximately 20% of the circumference of the tibial diaphysis, with an 80% bone column still providing support to the tibia, thereby negating the need for further support, for example, protection plates.

In summary, this method of ILN intermedullary rod extraction may provide a unique offering where proximal thread stripping has occurred and retrograde traction cannot occur due to the hourglass design or endosteal callous formation. In general, however, the application of the cortical bone windowing technique may appear more clinically relevant than custom-made jig application, and as such may be utilized with the standard thread-engagement extender system.

Ethical Approval

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. No ethical approval was required as this is a case study with no original research data.

Authors' Contributions

James Iversen contributed to the case management, data acquisition, and literature review, and wrote/reviewed the manuscript. Wye Li Chong, Jack Davey, and Jacob Michelsen contributed to the case management, data acquisition, and revision of the manuscript. Jacob Michelsen was the primary surgeon.

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Conflict of Interest

None declared.

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