

The treatment of femoral shaft fractures in children was reviewed in AO Dialogue (Volume 18, Issue II, October 2005). As a comparison, the present article briefly describes current trends in the treatment of similar fractures in immature dogs.

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Femoral fractures in young dogs

Although the femur of immature dogs and children present numerous anatomical similarities, the orientation of the hind/lower limb as well as the distribution of the thigh musculature are quite different between the two species, which in turn dictates and limits treatment options. Specifically, the medial aspect of the canine hind limb is, to a certain extent, attached to the abdominal wall and often rapidly tapers down from the hip to the knee. Because of these anatomical traits the use of external coaptation, such as casts or splints is ineffective and contra-indicated for the treatment of diaphyseal fractures, particularly in young, rapidly growing dogs. Conversely, because of its high success rate, surgical reduction and stabilization of

femoral shaft fractures is the treatment of choice regardless of the animal's age.

Depending on the breed, dogs reach skeletal maturity between 5 months (toy breeds) and 18 months (giant breeds) through a very rapid, biphasic growth rate (Fig 1b). During the initial growth phase, both structural and material properties of immature bone are considerably different from those of adult bone and are characterized by lower strength, and stiffness, as well as lower yield stress and elastic modulus [1–2]. In addition, the diaphyseal cortices are considerably thinner in young dogs compared to adults (Fig 1a-c). As a result, immature canine bone is

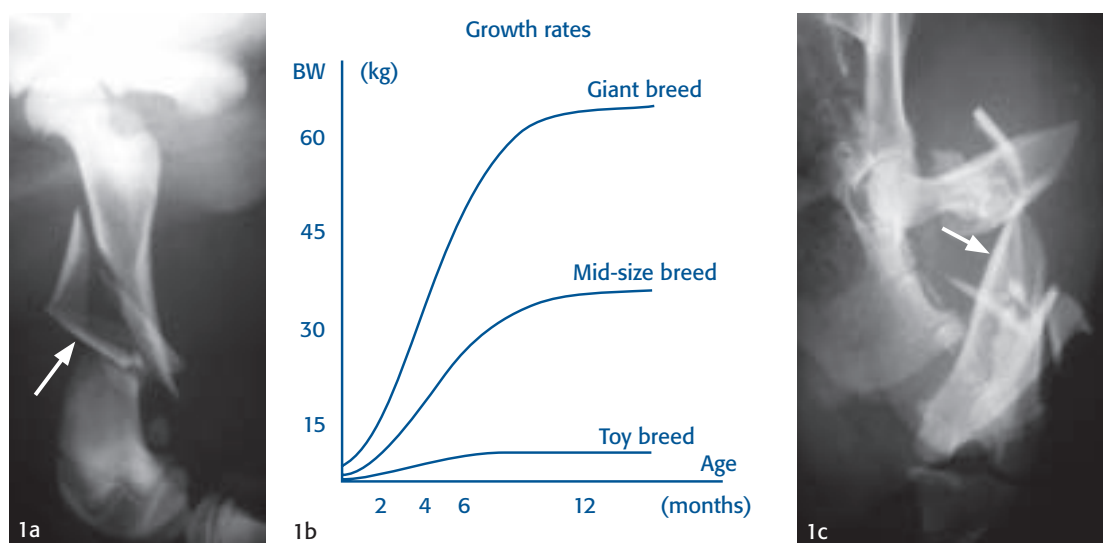
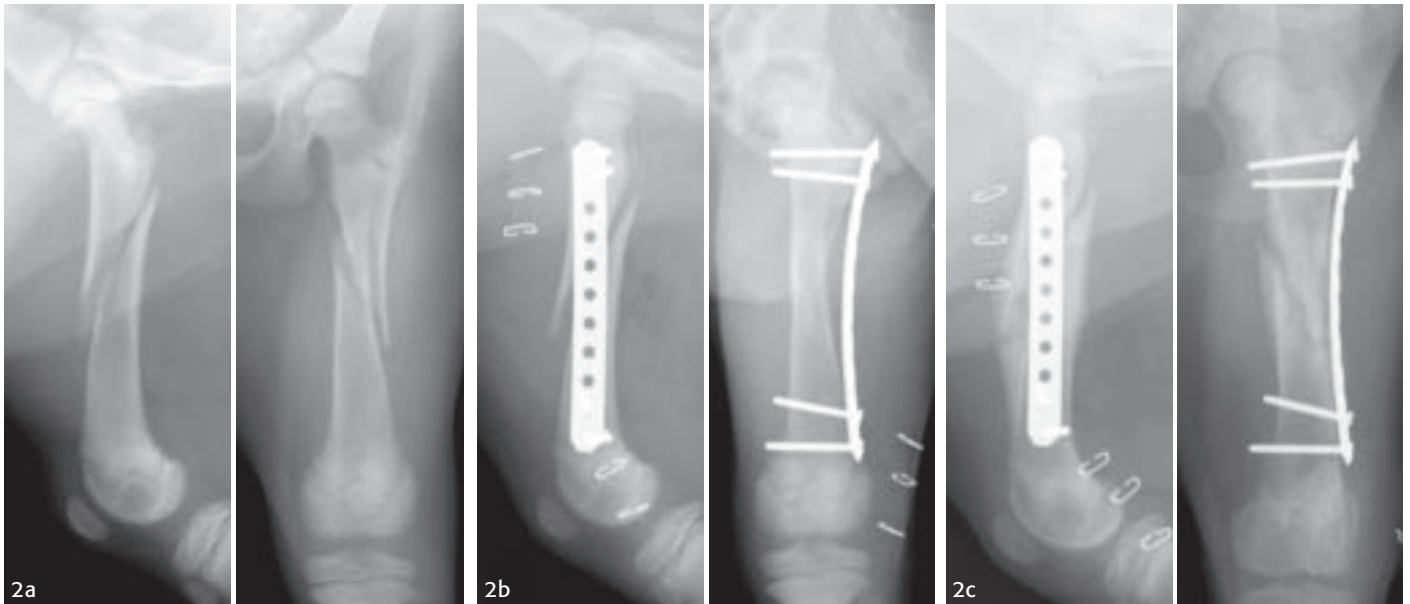


Fig 1 Diagram illustrating the difference in growth rates between dog breeds of various sizes (b). Skeletal maturity is reached between 5 and 18 months depending on the breed. X-rays of a comminuted diaphyseal femoral fracture in a 4-month-old puppy (a) and in an adult dog (c), illustrating the dramatic variation in cortical thickness with age (arrows). The lower biomechanical properties of immature canine bones, including strength and modulus, jeopardize the integrity of the bone/screw interface. (BW: body weight).



highly susceptible to implant failure via screw pullout. In addition, due to the rapid initial growth phase and the natural knee flexion angle (~140°), the immobilization of the knee in young dogs will ineluctably result in stiffening of the joint secondary to adhesion formation and quadriceps contracture [3]. Importantly, this so called “fracture disease” leads to irreversible loss of limb function even after short-term (a few days) immobilization. To prevent this debilitating complication, early post-operative mobilization is therefore essential, which in itself represents a real challenge in hyperactive, non-leash-trained puppies.

Surgical options

Classic intramedullary nailing Regardless of the osteosynthesis technique chosen, the capital, trochanteric and condylar physes must be preserved at all cost. This absolute requirement renders the use of normograde intramedullary devices such as pins or interlocking nails ill advised. Indeed, classic intramedullary nailing via the inter-trochanteric fossa has been associated with dramatic alterations of the femoral head and neck anatomy including coxa valga, hyper anteversion, small malformed femoral head, short thin femoral neck and coxofemoral subluxation [4].

Elastic stable intramedullary nailing (ESIN) While ESIN has been highly successful in children, this technique is not currently available in veterinary orthopedics. The adaptation of this technique in quadrupeds, along with the development of a large series of appropriately sized implants, may prove challenging in dogs due to the great variability of patient size and body weight.

External fixation The use of external fixation is poorly suited for the treatment of femoral shaft fractures in young dogs for several mechanical and biological reasons. The remote position of the external fixator frame away from the neutral axis of the femur accentuates the bending stresses at the pin/bone interface, which becomes an even greater stress riser. This poor biomechanical configuration promotes early failure via implant pullout even with use of positive cancellous profile trans-osseous pins. From a biological standpoint, the transfixation of the biceps femoris and vastus lateralis generates post-operative pain, precludes free range of motion at the knee, and routinely results in fracture disease (quadriceps contracture).

Plate osteosynthesis Due to the shortcomings of intramedullary nailing and external fixation techniques, plate osteosynthesis remains the treatment of choice for femoral diaphyseal fractures in juvenile dogs. However, strict adherence to the classic AO principles of anatomical reduction and rigid internal fixation during the early growth phase routinely results in catastrophic implant failure via screw pullout. The critical evaluation of these failures has led to the development of a new biological, elastic plate osteosynthesis technique (EPO) better suited to the treatment of femoral diaphyseal fractures in puppies [5]. The technique relies on the increased overall compliance of the femur/plate construct to reduce the risk of focal failure of the screw/bone interface. We have been using EPO in conjunction with minimally invasive surgical strategies (MIS) such as restoration of alignment rather than anatomical reconstruction and percutaneous sliding plate techniques to further decrease post-operative morbidity and optimize functional recovery.



Fig 2 X-rays of a long oblique, mid-diaphyseal femoral fracture in a 12 kg, 12-week-old, female mixed breed dog prior to (a) and after (b) elastic fixation using an 11-hole VCP 2.0 secured with four 2.0 mm screws. Postoperative x-rays showing clinical union at 14 days (c). Implant removal at 21 days shows advanced callus remodeling as well as restoration of alignment (d).

Elastic plate osteosynthesis

Fractures are repaired with Veterinary Cuttable Plates (VCP) applied via a lateral approach to the femoral shaft. The approach can be extended by partial (caudolateral) elevation of the proximal insertion of the vastus lateralis. The fracture hematoma is not removed because of its favorable effects on healing. The plate is applied according to the principles of bridge plating (use of a longer plate and fewer screws) [6]. Indirect fracture reduction is accomplished by traction on the distal fragment with small fragment forceps and/or by means of the plate. Sometimes the tip of a small fragment forcep is used to realign a large fragment or an oblique fracture, but without attempting a precise reduction.

Since anatomical reduction is not attempted, restoration of the femoral length is achieved by determining the appropriate plate length from cranio-caudal radiographic views of the contralateral intact femur. The plate is cut to the desired length according to the anticipated position of the screws in relation to the growth plates. The screws are placed in the two most proximal and the two most distal holes of the plates. The two proximal screws are inserted near the origin of the vastus lateralis muscle, their direction being influenced by the configuration of the fracture. The two distal screws are inserted proximally to the distal growth plate. Cortical 2.0 mm or 2.7 mm screws are inserted without tapping. Two adjacent screws should always be oriented in diverging planes in order to increase resistance to pullout. Closure is routine.

With this technique, the preservation of the strong periosteal sleeve, in conjunction with the use of an undersized implant

(VCP) allows controlled motion at the fracture site, which in turn promotes rapid bone healing via callus formation [7]. The flexural deformation of the femur/plate construct is achieved, in part, by controlling the working length of the implant (ie, the central section of the plate devoid of bone screws). From experience, the central plate span without screws should be as long as possible and include no less than 3 consecutive empty screw holes. This screw distribution decreases the stress riser effect of a single empty screw hole, thus reducing the risk of implant fatigue failure. Similarly, it increases the overall compliance of the repaired bone/plate construct and therefore reduces bone/screw interface stresses, which limits the risk of implant failure via screw pullout.

The outcome of elastic fixation using VCPs 2.0 and 2.7 has been evaluated in a series of 24 consecutive juvenile femoral fractures [5]. The working length of the plates encompassed from 7 to 20 adjacent empty holes. All plates were secured via two proximal and 2 distal cortical screws inserted without tapping. Clinical union occurred as early as two weeks and was achieved in all cases by four weeks post-operatively. Implant failure, whether from screw loosening or plate plastic deformation or fracture, was not found. In most cases, callus remodeling could be observed after two months and bony union was achieved by four months. Diaphyseal growth was undisturbed and consistently occurred without loss of alignment or anatomical deformation of either epiphyses (**Fig 2**).

Minimally invasive techniques

Minimally invasive [percutaneous] plate osteosynthesis (MI[P] PO) was recently combined with elastic fixation in an effort to

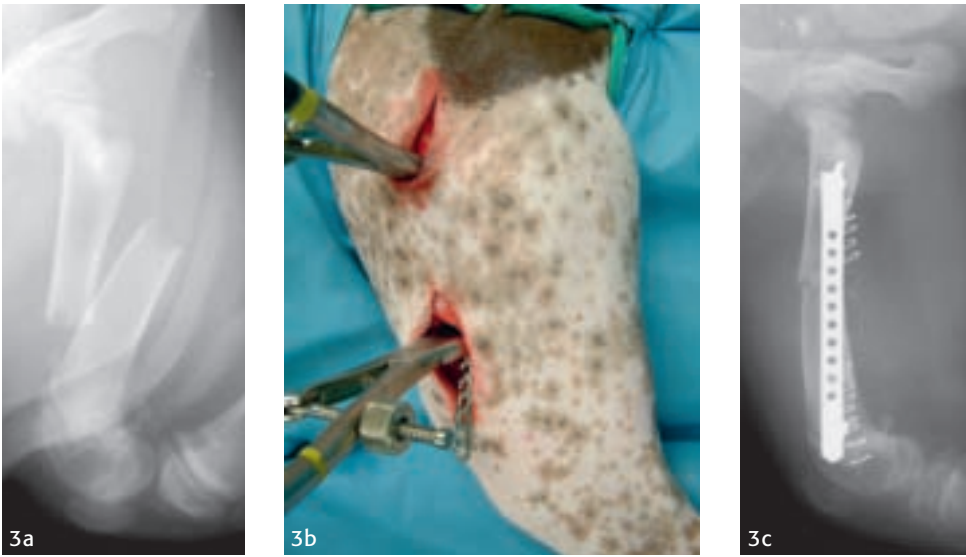


Fig 3 X-rays of a transverse, mid-diaphyseal femoral fracture in an 18 kg, 12-week-old, female German shorthair pointer (a). Intraoperative view illustrating fracture reduction and stabilization using MIPPO techniques (b). Alignment is maintained via two small Bishop bone reduction forceps placed in the subtrochanteric (top) and distal metaphyseal areas (bottom) through limited skin incisions and fascial dissection. A 16-hole VCP 2.7 is then percutaneously slid under the vastus lateralis from a proximal to distal direction (b) to achieve elastic fixation. Post-operative x-ray showing restoration of alignment (c).

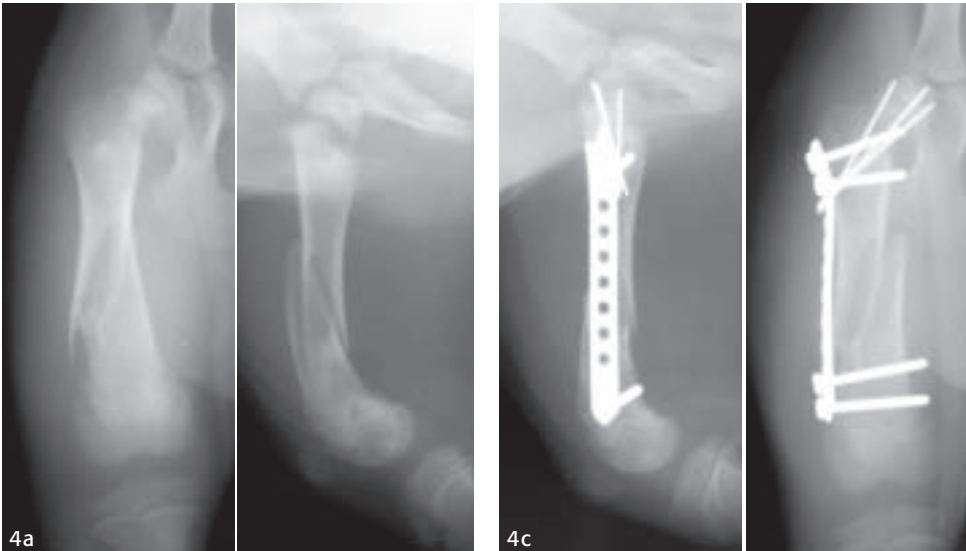
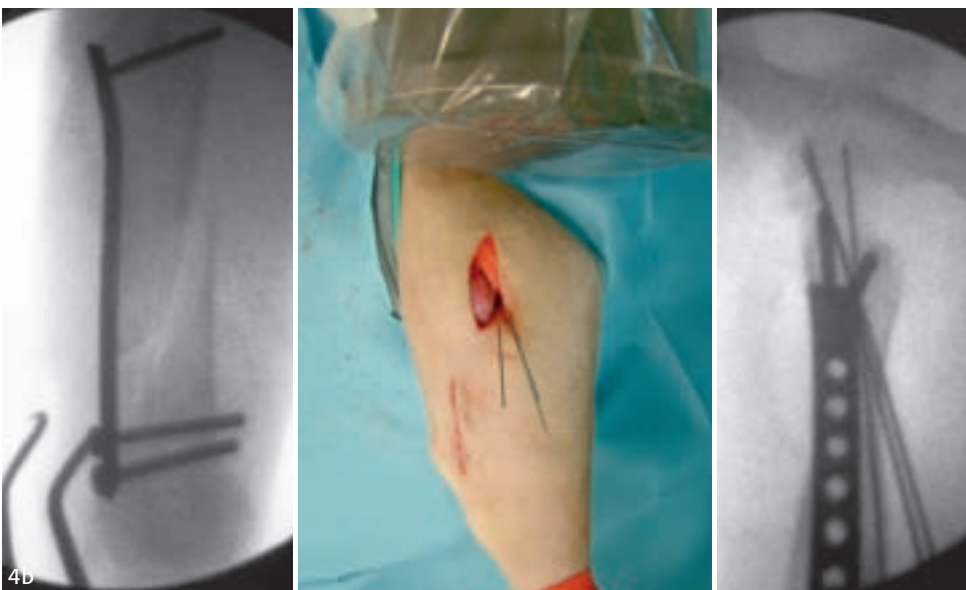


Fig 4 X-rays of a long oblique, mid-diaphyseal femoral fracture with a Salter I fracture of the capital physis in a 15 kg, 8-week-old, male Terrier (a). Intraoperative fluoroscopy (b) is used to verify alignment and proper implant position (inserts). This approach was combined with MIPPO and MIS techniques to effectively treat the diaphyseal and Salter fractures respectively. While anatomical reduction is not a primary focus when using MIPPO techniques, one must strive to restore limb alignment (c).



further reduce post-operative morbidity [8]. Here, cutaneous and fascial incisions are limited to the subtrochanteric and para-patellar regions on the lateral aspect of the femur (Fig 3). As with traditional “open but do not touch” approaches, restoration of alignment is achieved via small bone forceps. Using the cranio-caudal radiograph of the contra-lateral femur, the VCP is cut to length, bent proximally to follow the subtrochanteric flare and twisted distally along the lateral surface of the distal metaphysis. The contoured plate is then slid underneath the vastus lateralis from either direction and secured to the proximal and distal metaphyses (Fig 3). Since the fracture site is not exposed, it is beneficial to verify proper alignment via intra-operative fluoroscopy (Fig 4). By virtually eliminating exposure of the fracture site, this approach helps preserve the fracture hematoma, a critical step in enhancing bone healing [9]. In addition, it minimizes damage to the soft tissues (muscles, fascia and periarticular retinaculum) thus reducing scar tissue formation and promoting early use of the fractured limb. Both factors have been shown to be greatly beneficial in children and are likely to show similar advantages in young dogs.

Postoperative care

Although weight bearing and range of motion are recommended immediately after surgery, high impact activities (jumping, rough play), while difficult to control, should be avoided. In contrast, physical activities such as leash walking, trotting, and swimming or wading are beneficial. Professional physical rehabilitation using an underwater treadmill is rarely needed in puppies that are naturally active.

One must keep in mind that the single most important factor contributing to the success of this new surgical approach (EPO) to femoral fractures in immature dogs is the higher construct compliance, which reduces the risk of screw pullout. Second, by promoting rapid bone healing and by minimizing iatrogenic soft tissue injuries, the use of minimally invasive techniques (MIPPO) optimizes early functional recovery.

Bibliography:

1. **Torzilli PA, Takebe K, Burstein AH, et al** (1981) Structural properties of immature canine bone. *J Biomech Eng*; 103:232–238.
2. **Torzilli PA, Takebe K, Burstein AH, et al** (1982) The material properties of immature bone. *J Biomech Eng*; 104:12–20.
3. **Bardet JF, Hohn RB** (1983) Quadriceps contracture in dogs. *J Am Vet Med Assoc*; 183:680–685.
4. **Black A, Withrow S** (1979) Changes in the proximal femur and coxofemoral joint following intramedullary pinning of diaphyseal fractures in young dogs. *Vet Surg*; 8:19–24.
5. **Cabassu J** (2001) Elastic plate osteosynthesis of femoral shaft fractures in young dogs. *Veterinary and Comparative Orthopaedics and Traumatology*; 14:40–45.
6. **Schatzker J** (1995) Changes in the AO/ASIF principles and method. *Injury*; 26:51–55.
7. **Grundnes O, Reikeras O** (1993) Effects of instability on bone healing. Femoral osteotomies studied in rats. *Acta Orthop Scand*; 64:55–58.
8. **Cabassu JP, Dejardin LM** (2005) Minimally Invasive Plating. *American College of Veterinary Surgeons 15th Annual Symposium*; CD ROM Proceedings.
9. **Grundnes O, Reikeras O** (1993) The importance of the hematoma for fracture healing in rats. *Acta Orthop Scand*; 64:340–342.



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