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Distal femoral osteotomy using a novel deformity reduction device

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Keywords

Patellar luxation, jig, limb alignment, deformity, distal femoral osteotomy, dog

Summary

Distal femoral osteotomy is a surgical procedure used to correct patellar luxation, secondary to a femoral deformity. A distal femoral osteotomy using the tibial plateau levelling osteotomy-jig to temporarily provide stability of the distal femoral osteotomy, maintaining limb alignment in the frontal and axial planes prior to internal plate fixation of the osteotomy, has been described. This report describes a novel jig named Deformity Reduction Device (DRD). This device was developed with the specific aim of increasing precision and predictability during corrective osteotomy execution in order to be consistent with the preoperative planning. The distal femoral osteotomy DRD-assisted procedure is described in detail, discussing the theoretical and practical principles of the application.

Introduction

Distal femoral osteotomy is a surgical procedure used to correct patellar luxation secondary to femoral deformity. A distal fe- moral osteotomy is often combined with other surgical procedures such as tibial tuberosity transposition, wedge or block trochleoplasty and soft tissue desmotomy or imbrication in order to allow the patella to track normally (1, 2). Excessive distal femoral varus or valgus can be corrected by performing a distal femoral osteotomy; both opening wedge osteotomy and a closing wedge ostectomy have been used successfully to achieve improved limb alignment (1, 3). Recently there has been an increased interest in veterinary orthopaedics in regard to improvement of limb and joint alignment using the centre of rotation of angulation (CORA) methodology as part of the management of canine patellar luxation, and as described in human orthopaedics (4). The CORA methodology has been used to describe the normal relationship of the canine stifle joint to both the anatomical and mechanical axes of the canine femur in the frontal plane (5). Use of the tibial plateau levelling osteotomy jig to temporarily provide stability of distal femoral osteotomy, maintaining limb alignment in the frontal and axial planes prior to internal plate fixation of the osteotomy has been described (1, 3). The tibial plateau levelling osteotomy jig provides only relative stability after the osteotomy, so it is generally used in combination with bone reduction forceps or divergent Kirschner wires prior to bone-plate fixation. The purpose of this report is to describe a novel deformity reduction devicea (DRD) and the technique of performing a distal femoral osteotomy assisted by this device for the management of patellar luxation.

Deformity reduction device description

The DRD performs essentially as an external fixator, temporarily stabilizing the bone segments. The DRD is composed of an arch connected to an interchangeable rod via a cannulated hinge (▶Figure 1). The rod length can either be 4 cm or 6 cm resulting in the overall length of the DRD being 11 or 13 cm, respectively. The rod diameters are 4 mm. The rod position can be translated 10 mm medially or laterally by loosening the dedicated holding screw securing the rod to the hinge. A graduated scale in 1 mm increments is etched on the jig for reference (▶Figure 2). The hinge of the DRD allows for a total of 120° of varus or valgus correction: 60° in either direction from neutral, which is defined as the position when the arch and the rod are perpendicular to each other. A graduated scale in five degree increments is etched into the hinge for reference (▶Figure 2). The central screw of the hinge is cannulated to accept a 1.5 mm Kirschner wire to aid in DRD positioning on the bone. The hinge axis can also be translated 15 mm either medially or laterally from a neutral position, by using the adjustable micrometric screw (▶Figure 2). The arch of the DRD has a 70 mm internal diameter and is slotted to accept Meynard clamps. The arch can allow 90° of rotation for internal or external torsional correction: 45° clockwise or counterclockwise from the neutral position, by adjusting the micrometric screw. A graduated scale in five degree increments is etched onto the slotted arch for reference (▶Figure 2). The Meynard clamps are used to secure the DRD to the bone proximal and distal to the osteotomy site by using 2, 3 or 4 mm diameter holding pins. The clamp secures either rod and arch of the DRD by compressing the two halves of the clamp with an 8 mm bolt (▶Figure 2). The three principle components of the DRD (hinge, arch and rod) can be moved independently of each other by adjusting any one of the three micrometric screws with an 8 mm hexagonal wrench. By adjusting the hinge axis, the surgeon can accurately rotate the bone segments around either a neutral, closing or opening angulation correction axis CORA based on the preoperative deformity correction planning. Once the osteotomy or ostectomy has been completed, adjustments to the jig using the three micrometric screws and the graduated scales on the rod, hinge and arch allow precise and controlled osteotomy manipulation to achieve deformity correction and limb alignment prior to internal plate fixation.

Preoperative set-up of the deformity reduction device

True craniocaudal, mediolateral, and axial views of the affected femur are obtained. The proximal and distal anatomical axis are drawn as previously described (4). The magnitude of the CORA is measured and the transverse bisector line (tBL) is drawn. A closing or opening angulation correction axis (ACA) is chosen to correct the distal femoral misalignment, based upon the surgeon's preference for creating either a closing wedge ostectomy or an opening wedge osteotomy, respectively (▶Figure 3). To reduce surgery time, the DRD is adjusted preoperatively to closely resemble the orientation of the distal femur based on the measured CORA magnitude, desired ACA- CORA location and degrees of distal femoral torsion, if present. The angulation of the DRD at the hinge is adjusted to equal the preoperative CORA magnitude for varus or valgus deformity. The hinge is translated either left or right from neutral, using the adjustment screw, so that the orientation of the hinge axis will correspond to the de- sired ACA-CORA location (opening or closing wedge). The rod is translated, if necessary, so that it is superimposed over the proximal anatomical axis of the femur. Torsion of the distal femur, if present, can be quantified by a computed tomography imaging or axial radiographic view. The arch of the DRD can be rotated clockwise or counterclockwise, as needed in the axial plane to equal the degree of distal femoral torsion.

Distal femoral deformity reduction device assisted

A standard lateral or medial approach to the distal femur and stifle is performed based upon the surgeon's preference. The chosen ACA-CORA location and osteotomy site are identified, as determined by the preoperative deformity planning as previously described. A 1.5 mm Kirschner wire is inserted perpendicular to the cranial cortex of the femur, at the ACA-CORA location (▶Figure 4). A stopper device (▶Figure 5A) with a 1.5 mm central cannulated hole is placed onto the Kirschner wire to facilitate positioning of the DRD. The cannulated screw of the hinge is placed over the Kirschner wire, and the device slid along the wire until it is 1–2 cm from the cranial cortex of the femur. Care must be taken that the femoral trochlea is centred within the arch in the axial plane (▶Figure 5 B, C). To confirm the DRD position, a centre aiming arm can be attached to the arch to temporarily aid in centring the femur. The stopper nut is placed against the bottom surface of the DRD and secured to the Kirschner wire using a 1.5 mm hexagonal Allen wrench. The latter maintains a constant distance between the DRD and the cranial cortex of the femur while it is secured to the bone. The DRD hinge axis and central rod can also be translated medially or laterally, if needed, in order to position the jig correctly in relationship to the diaphysis and femoral condyle. The goals of DRD positioning are: 1) the cannulated hinge centred over the desired ACA-CORA location, 2) the femoral trochlea centred in the arch, 3) the central rod of the DRD centred over the femoral diaphysis and parallel to its longitudinal axis (▶Figure 6). The use of fluoroscopy is recommended to ensure the proper overlapping of the rod with the anatomical axis of the proximal femur. Once the DRD is properly positioned over the distal aspect of the femoral diaphysis and condyle, it is temporarily secured to the femur using four threaded external fixation pins and four Meynard clamps. Two clamps and 2.0–3.0 mm external fixation pins are placed from the central rod into the femoral diaphysis proximal to the location of the osteotomy. Fixation pins are inserted cranial to caudal engaging the caudal femoral cortex. Ideally the fixation pins are placed distal to where the proximal extent of the bone plate will be positioned. Prior to placing the proximal fixator pins, it is imperative that the DRD is properly orientated in relationship to the distal femur and trochlear groove, as previously described. Two additional Meynard clamps and 2.0-3.0 mm fixation pins are inserted from the arch into the para-trochlear (non-weight bearing) region of the femoral condyle. Fixation pins can be inserted into alternating sides, or into the same side of the para-trochlear region of the condyle. Placing both distal fixation pins into the para-trochlear region of the condyle opposite from where the bone plate will be located will minimize interference of the fixation pins with plate and screw application. Once all fixation pins are inserted, all four Meynard clamps should be tightened. An opening wedge osteotomy or a closing wedge ostectomy is performed, as determined from the preoperative planning, using an oscillating saw. The 1.5 mm Kirschner wire placed through the ACA- CORA is removed prior to completing the osteotomy. The DRD maintains stability once the osteotomy or ostectomy is completed. Using the 3.5 mm hexagonal Allen wrench, the three micrometric screws on the DRD are adjusted, as indicated, to correct the femoral deformity in the frontal and axial planes (▶Figure 7). Once limb alignment has been achieved, permanent internal fixation is performed using a bone plate and screws (▶Figure 8A). The DRD and temporary fixation pins are removed (▶Figure 8B). Other ancillary surgical procedures such as block or recession trochleoplasty, desmotomy or imbrication of joint tissues, and tibial tuberosity transposition are performed at the surgeon’s discretion and depending on severity of the luxation. The surgical approach to the distal femur and stifle are closed in a routine fashion. Postoperative craniocaudal, mediolateral and axial radiographic views of the limb should be obtained to access deformity correction and implant positioning (▶Figure 8C).

Discussion

Accurate correction of the deformity without creation of a secondary deformity depends on precise localization and quantification of the deformity. With the DRD, the surgeon can decide to centre the ACA at the level of the CORA to match the preoperative planning during the surgical procedure. When using the tibial plateau levelling osteotomy jig, relative stability is achieved because it functions as a temporary 2 pin type I-A external fixator with one fixation pin above and one below the osteotomy site. In fact, after the osteotomy or ostectomy, bone reduction forceps, Kirschner wires, or both, must be used to temporarily maintain the reduction during plate application. Torsional correction can be done with the tibial plateau levelling osteotomy jig by bending one pin of the jig, however this may lead to translational deformity because the centre of rotation is not superimposed with the centre of the bone. This secondary deformity is corrected free-hand because of the free movement of the jig. When using the DRD, application of the bone plate is performed with the osteotomy stabilized by the two pins proximal and two pins distal to the osteotomy site, without any help by assistant or reduction forceps to maintain the reduction. The amount of angulation and torsional correction can be directly visualized on the graduate scales of the arch and the hinge. To perform accurate rotational osteotomy without any translation, the centre of the arch must be superimposed over the centre of the bone. If the arch is well positioned, it will allow precise torsional correction, minimizing the translation of the segments. Any other translational movement can be achieved through the two translational mechanisms to improve the bone contact at the level of the osteotomy if needed. The pins can be inserted through the surgical approach or through the skin in order to minimize the extent of the surgical approach. The type of osteotomy is chosen according the surgeon’s preference. If an opening wedge osteotomy is desired, it is suggested to perform the osteotomy exactly where the Kirschner wire is inserted because of geometrical reasons, in order to avoid conflict between the two bone apices during correction of the deformity. The osteotomy is usually performed at the level of the CORA, but in juxta-articular deformity, the ACA can be moved away from the CORA to gain enough space for further plate application. The amount of translation at the osteotomy site that is necessary for correction of the deformity is determined preoperatively and can be attained reliably during the procedure. Precise preoperative planning and application of the CORA methodology is mandatory to properly use the DRD, otherwise it will lead to malalignment. The right sequence of the deformity correction using the DRD is to correct first the angulation and then the torsion since the arch moves independently from the hinge that remains in the same position. In fact, the ACA changes position in relation to torsional correction, but the Kirschner wire and the hinge will always remain in the same plane. If torsional correction is done first, the subsequent correction of the angulation will lead to malalignment. Further prospective clinical evaluations of the DRD to correct distal femoral misalignment are warranted. The DRD can potentially be applied in all the deformities and in other anatomical segments. However, for distal femoral osteotomy, due to its dimensions, usage should be limited to patients over 15–20 kg body weight. Although this technique may lend itself to stabilization of the osteotomy with plate and screws, alternative techniques such as an interlocking nail are not possible with this system due to external fixation pins that prohibit the placement of an intramedullary interlocking nail intra-operatively. Similar to human orthopaedics, we think that the DRD could improve the precision and the predictability of deformity correction (6). The deformity correction could be done with internal or external fixation. Both have advantages and disadvantages. External fixation could allow for a more precise biological and adjustable corrective osteotomy in comparison with plate and screws fixation. Otherwise internal fixation has less postoperative management and morbidity for the patient. Using temporary external fixation and definitive internal fixation, the surgeon can combine the advantages of both techniques.

Conflict of interest

Authors Enrico Panichi and Antonio Ferretti are the inventors of the DRD and they receive royalties from Hofmann srl, which produces and commercializes the instrument and owns the patent of the DRD Jig.

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Figure 1

Deformity reduction device components: 1) arch, 2) adjustment screw for arch rotation (torsional correction), 3) hinge, 4) adjustment screws for hinge angulation (varus/valgus correction), 5) adjustment screw for hinge translation, 6) adjustment screw for rod translation, 7) rod.

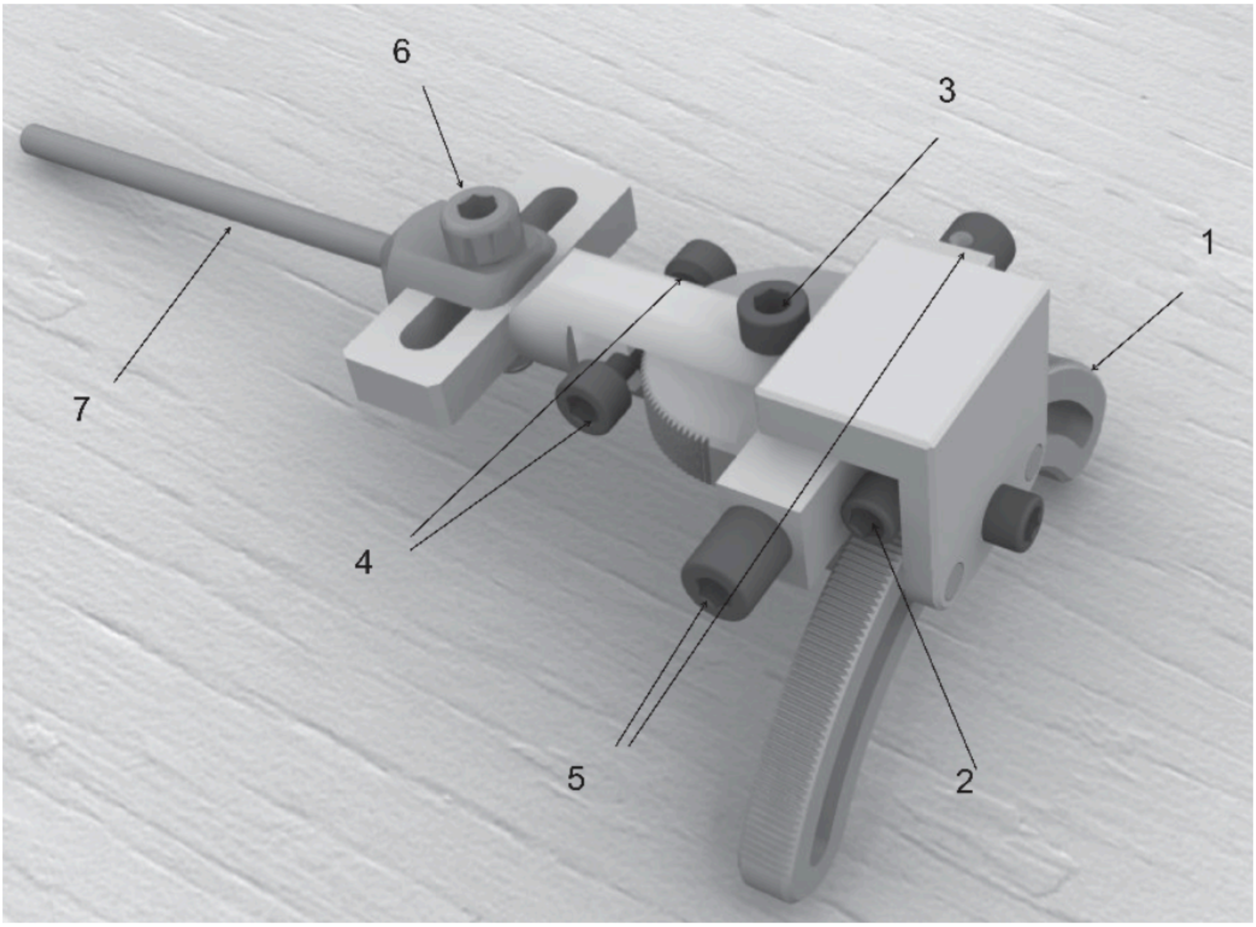

Figure 2 **Deformity reduction device (DRD) features: A) the hinge allows for 120° of angulation (varus/valgus correction): 60° in either direction from neutral; B) translation of the hinges 15 mm either medially or laterally from a neutral position; C) translation of the rod 10 mm medially or laterally by loosening the screw; D) 90° of rotation of the arch (internal/ external torsional correction): 45°clockwise or 45° counterclockwise from the neutral position; E) Meynard's clamps to secure four pins, two above and two below the osteotomy site.**

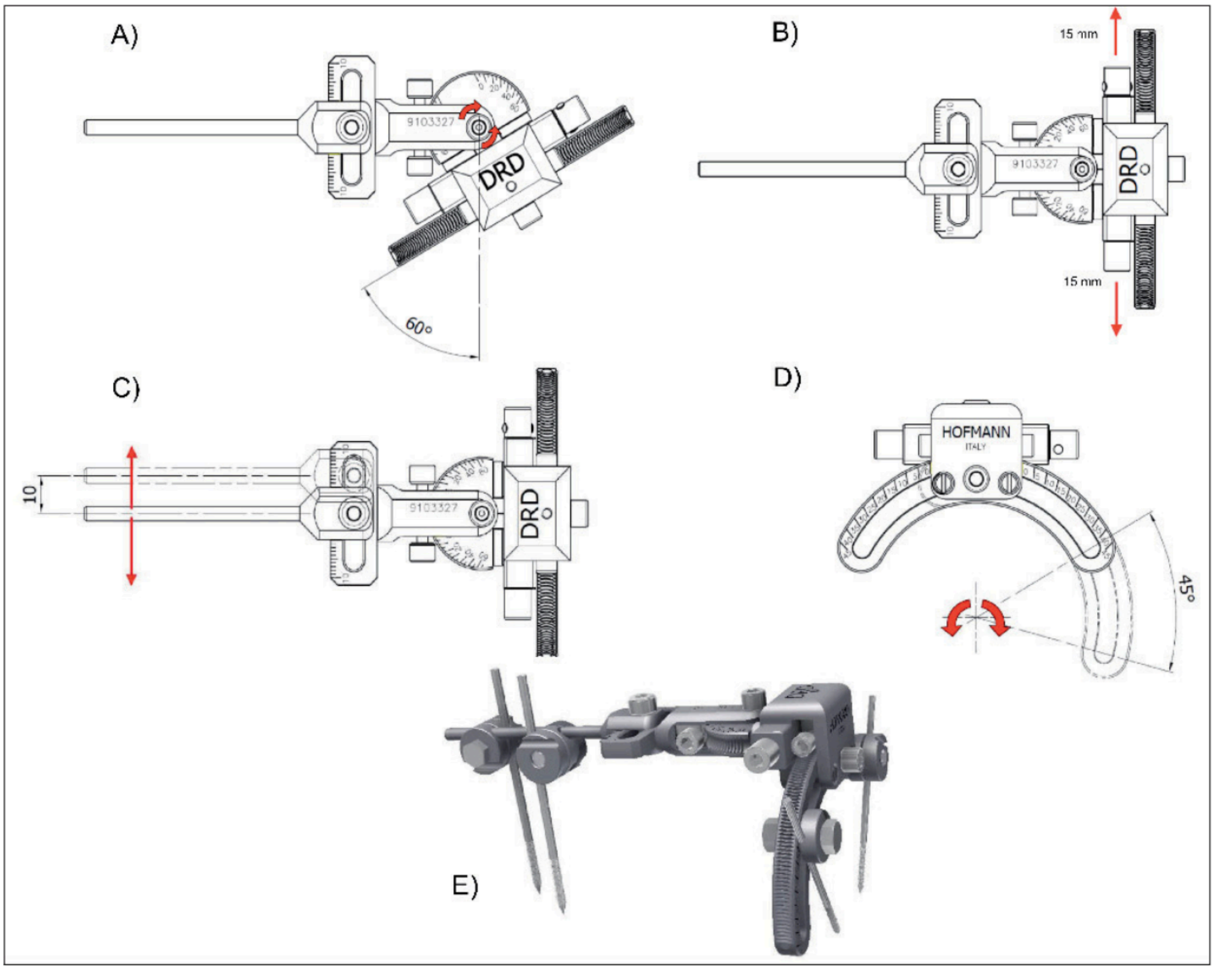

Figure 3 **A) The anatomical axis lines create two supplementary angles (α and β). B) The transverse bisector line (tBL) divides the B angle into two equal halves (β/2). All of the points on the transverse bisector line are centres of angulation (CORA). C) Angulation correction axis (ACA) at the level of the medial cortex for correction of varus deformity by a closing wedge ostectomy. D) The ACA at the level of the lateral cortex for correction of varus deformity by an opening wedge osteotomy.**

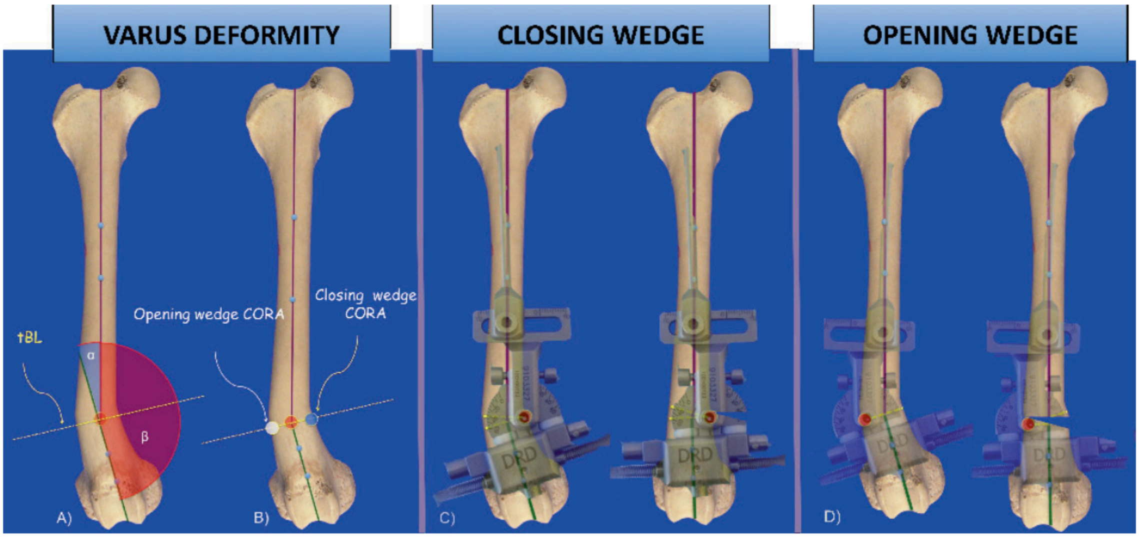

Figure 4

A 1.5 mm Kirschner wire is inserted through the cranial cortex of the femur, perpendicular to the longitudinal axis and at the angulation correction axis – the centre of rotation of angulation location.

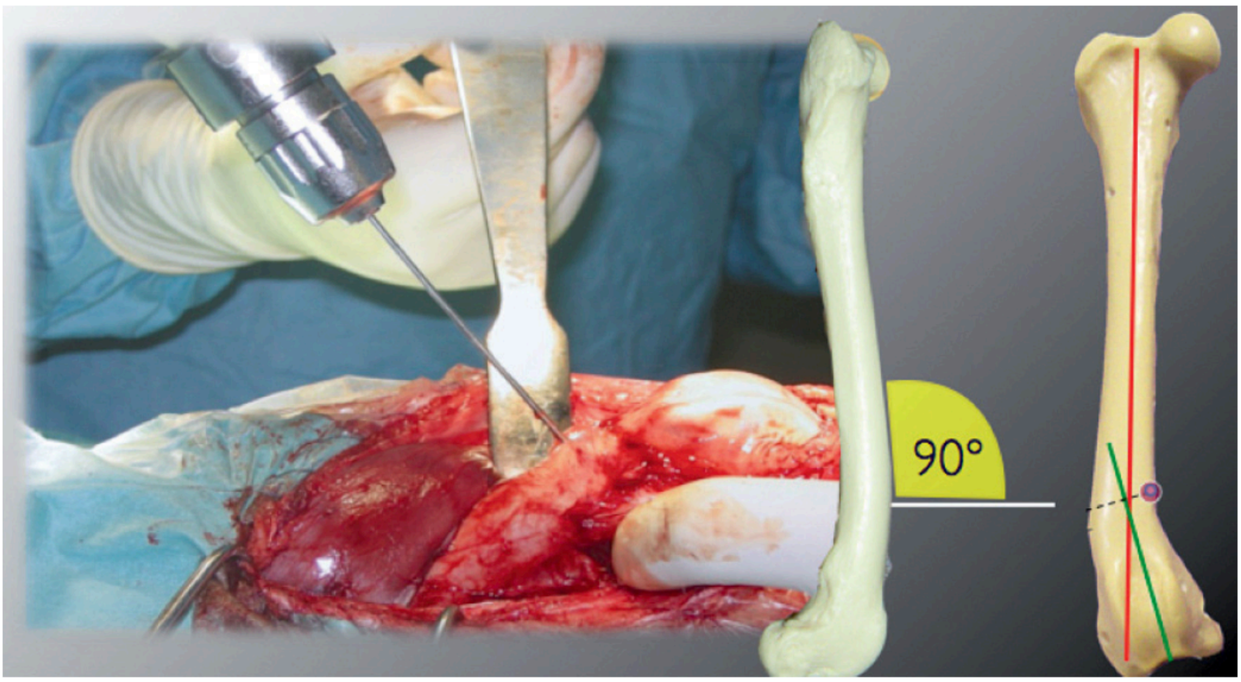

Figure 5 A) The stopper nut (white arrow) maintains a constant distance between the deformity reduction device and the cranial cortex of the femur while it is secured to the bone (yellow arrow). A centre aiming arm can be attached to the face of the arch to temporarily aid in centring the arch over the bone in the axial plane. B) Incorrect positioning. C) Proper positioning: the centre of the arch (yellow dot) is superimposed with the centre of the bone (identified with x).

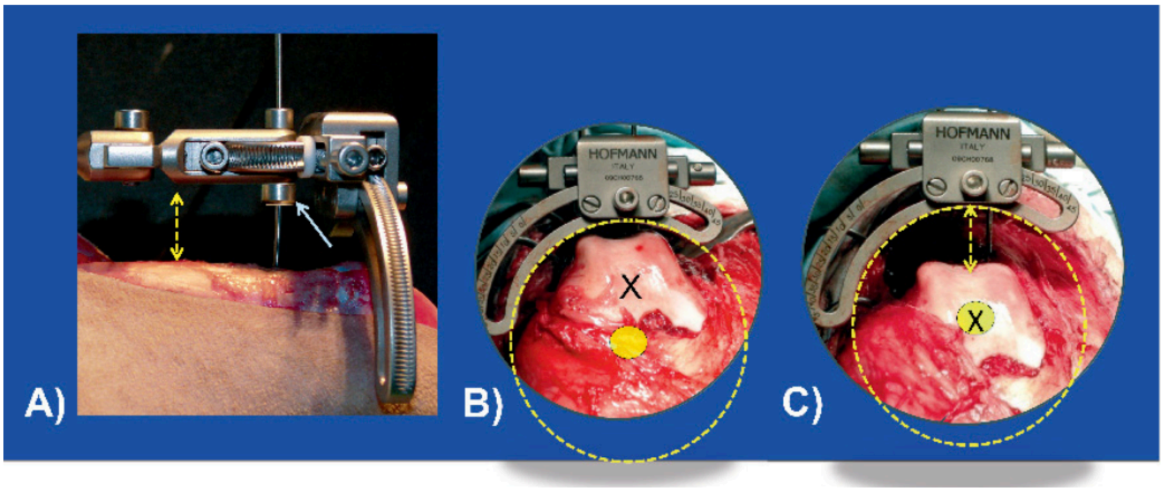

Figure 6 Deformity reduction device application on the femur: A) frontal, B) axial, and C) sagittal view.

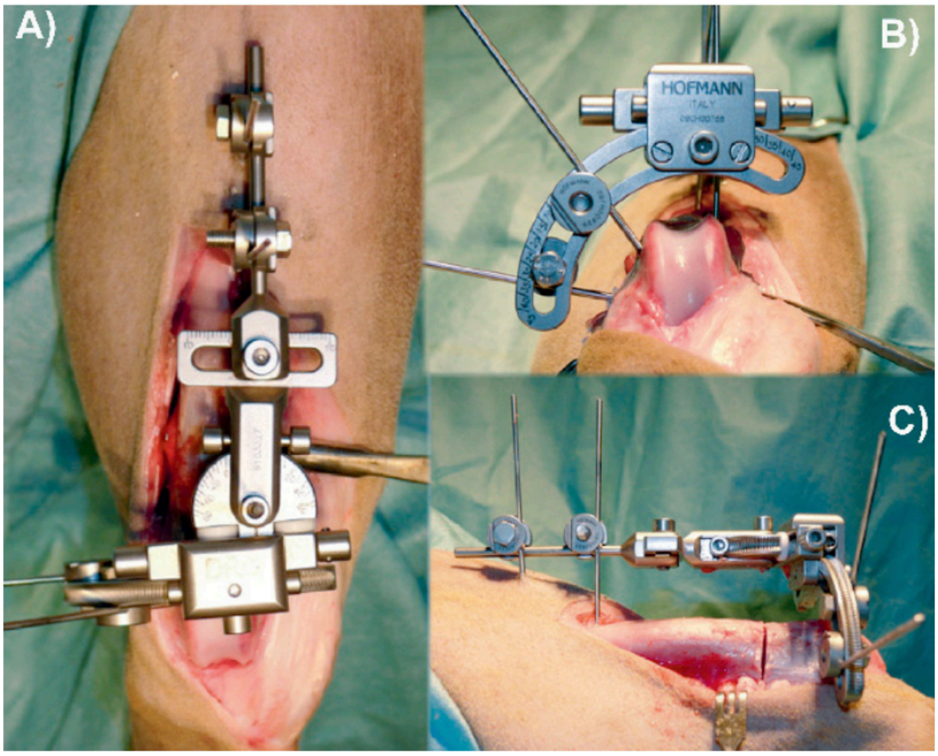

Figure 7: Closing wedge ostectomy for distal varus deformity of the femur. A) Bone gap after bone wedge removal. B) The 20° degrees of varus deformity to correct is indicated on the graduated scale. C) Bone segments apposition at the osteotomy site after correction. D) The graduated scale confirms the amount of correction performed.

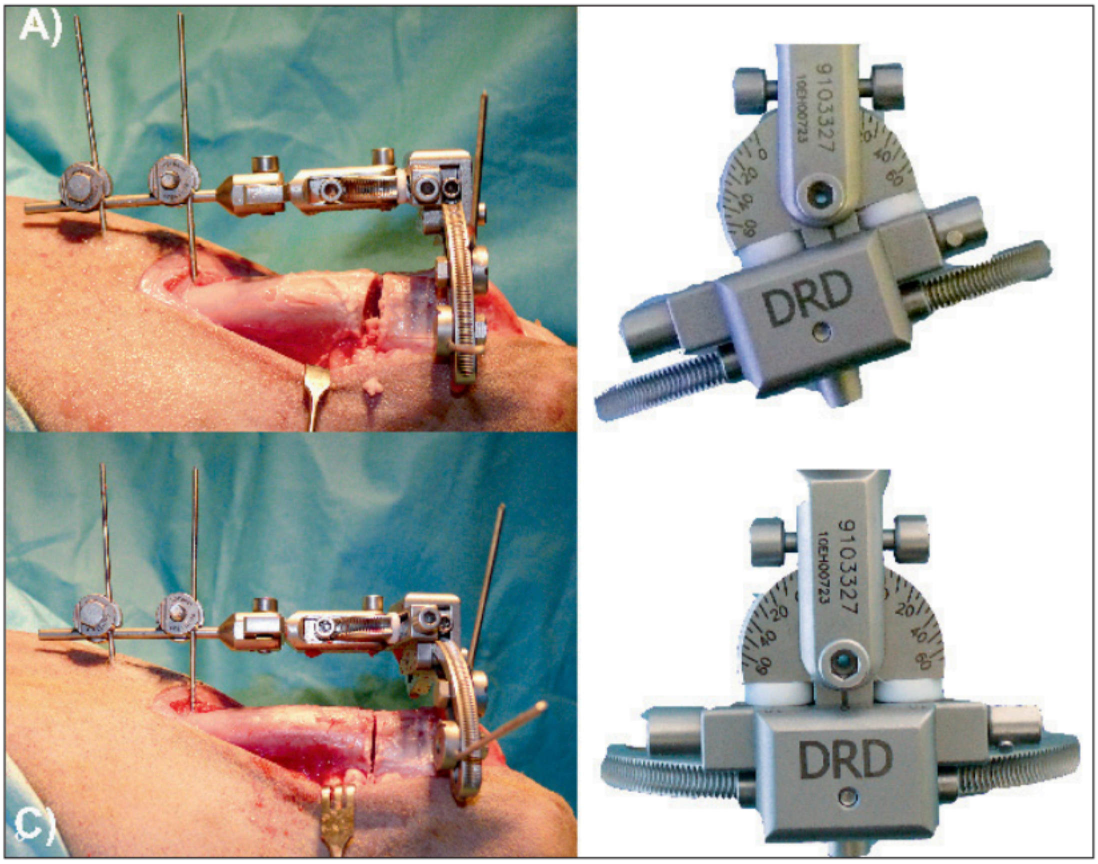

Figure8A) Plate application in stable condition of the osteotomy site. B) Deformity reduction device (DRD) jig removal. C) Boxer M nine months old, medial patellar luxation 2° degree: correction of varus and external torsional deformity of the femur was achieved using the DRD jig and the osteotomy was fixed with a Fixin locking L-shaped plate and 3.5 mm screws.