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How to Optimize Elastic-Stable-Intramedullary-Nailing (ESIN) for the Treatment of Paediatric Femoral Fractures: What are the Options when the Method Reaches its Limits?

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Abstract

Since the introduction of the Elastic-Stable-Intramedullary-Nailing (abbreviation ESIN) in 1983, by the Nancy group, the method has become a worldwide standard in the treatment of pediatric long bone fractures. When all the biomechanical principles are respected, the vast majority of paediatric long bone diaphyseal fractures can be successfully treated between the ages of 3 and 15 years. The method is particularly suited to management of diaphyseal femoral fractures. Treatment failure of most often occurs when used by inexperienced surgeons in situations where the method is only relatively indicated. Such as the metaphyseal-diaphyseal junction or axially unstable injuries, particularly in the taller and/or heavier child. Whilst an expert may achieve success in such circumstances the less experienced surgeon will often resort to more invasive methods. The ESIN method is generally contraindicated for the management of epiphyseal injuries. The commonest reason for failure, even when the method is used for the correct indication, is usually a combination of lack of training, experience and/or technical skill resulting in incorrect execution of the technique and consequently either a suboptimal outcome, where healing is achieved without the benefits of more rapidly achieved reduction, pain relief, healing, return of function and shorter treatment times. Unfortunately these cases are often reported as good outcomes but we should strive for excellence. Worse still poor outcomes are those when poor case selection and/or poor technical execution produces a worse situation than if conservative management had been undertaken.

Keywords: Elastic-Stable intramedullary nailing; ESIN; Complication; ESIN limits; Femur fracture; ALFN; End Caps; Cork screw phenomenon

Introduction

The goal of this short article is to identify ways in which case selection, pre-operative planning, excellence in technique and appropriate use of advanced techniques can reduce the risk of avoidable complication and/or identify intra-operatively technical failures and how to rectify them and avoid the need for revision surgery and when to select an alternative treatment method.

Learning Outcomes

At the end of this article you should be able to:

1. Realize that the child's age, weight, diameter of the medullary canal, fracture pattern and location are the principle factors limiting the use of the ESIN method.
2. Analyse the complexity of the fracture morphology according the Pediatric Fracture Classification.
3. Explain how we can improve the stability of the ESIN method.
4. Describe which methods for fracture stabilization are suitable for older children.
5. Formulate which are the special morphological features of the femur in adolescence.

Challenges in ESIN

It is mandatory to apply the ESIN method using the correct technique; this means that there is a requirement for 2 elastic nails to achieve good 3-point contact within the bone to produce balanced, equal and opposing forces as shown in the illustration (Figure 1A) and in the x-ray (Figure 1B). The fixation points for each nail are the entry point, contact between the nail and the inner cortex of the medullary canal and anchorage of the nail tip in the metaphysis it is impacted into. Even long spiral fractures can be successfully stabilized when this is achieved [1-3].

The ESIN method works best when there is and intact periosteal sleeve and rapid formation of good quality callus, therefore in older children or those with severely disrupted soft tissue we sometimes see delayed healing [4,5]. The x-ray below (Figure 2) shows formation of a good callus although there are aspects of technique that can be criticized particularly that the nails appear to be crossing at the level of the fracture and an ascending technique appears to have been used for a distal fracture.

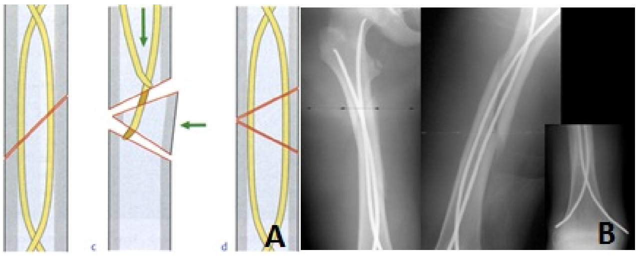

Figure 1 (A): The 3-point contact within the bone produces the equal balance of the fixations and is the guarantee for stability in oblique and comminuted fractures. **(B):** This x-ray demonstrates this 3-point contact and inner cortex contact over a long zone which allows stabilizing such long spiral femoral fractures.

Figure 2: This X-ray, 4 weeks postoperative, shows formation of a good callus although there are aspects of technique that can be criticized particularly that the nails appear to be crossing at the level of the fracture.

There is a relationship between the child's age and healing time [4]. Of the two radiographs below (Figure 3) the one on the left shows healing by callus formation in a younger child, treated with ESIN and the one on the right a lesser degree of callus formation in an older child, treated with an Adolescent Lateral Femoral Nail (an interlocked intramedullary nail) which is a more rigid form of osteosynthesis.

Another important factor that influences the indication for ESIN is the diameter of the medullary canal. The ratio of canal diameter to diameter of the bone changes with the age; in the very young child 3-7 years of age the canal is relatively very wide and the ratio will be typically greater than 3:1. This in the presence of a shorter bone will demand greater curvature during pre-bending and entry points as close to the physis as possible with impaction in to the metaphysis or a single pass across the physis to anchor the nail tips in the epiphysis. During later childhood 8-12 years of age the ratio reduces to approximately 3:2 and it is in this age group where the method is optimally applied. Around puberty the cortex is usually much thicker the ratio reducing to approximately 2:3 and the medullary canal whilst perhaps in actual terms is larger is proportionately very narrow as demonstrated in the illustration below (Figure 4).

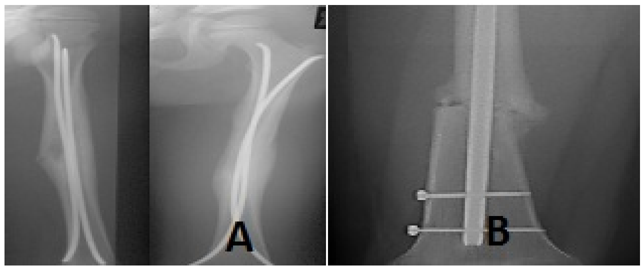

Figure 3 (A): The one on the left shows healing by callus formation in a younger child, treated with ESIN. **(B):** The one on the right a lesser degree of callus formation in an older child, treated with an Adolescent Lateral Femoral Nail (an interlocked intramedullary nail) which is a more rigid form of osteosynthesis.

This in a taller heavier child with more muscle mass means that the diameter of nail required to produce the force by pre-bending that is required to maintain fracture reduction is greater and it is not always possible to insert sufficiently pre-bent nails of the required diameter in such circumstances.

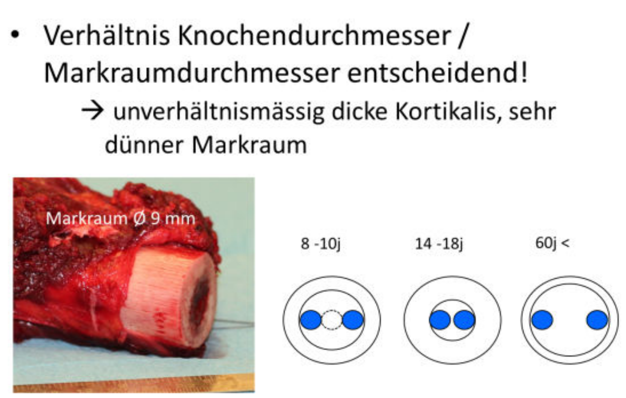

Figure 4: This figure shows the influence of the age concerning the relation between thickness of the cortex and the diameter of the medullary canal; on the left side a femur resection in a 14y old boy (TU); we see the narrow canal and thick cortex. The graphics demonstrates the changing of this relation in different ages.

As a general rule the arbitrary limits of the technique are determined at the youngest as children age 3 and in older children those of up to 170 cm in height or up to 50 Kg in weight although with advanced techniques such as the use of "EndCaps" femoral fractures in children up to 60 Kg in weight have been successfully treated by this method [1,2,4,6,7].

Failures of technique resulting in avoidable complications

- Wrong diameter of the nail (too thin/too thick)
- Nails of different diameter
- Nails pre-bent to a different degree
- Insufficient contouring of the nails to produce maximum contact with the inner cortex of the medullary canal
- Insufficient contouring of the nails to produce separation between the nails at the level of the fracture
- Different or asymmetrical entry points
- Insufficient anchorage in the fragment in which the entry points are made (fragment too short) usually optimal fixation is achieved when the nails are inserted into the longer fragment passing into the shorter fragment
- Insufficient anchorage in the metaphysis of the fragment the nail tips are impacted into (fragment too short)
- Entry points too close together (secondary fracture)
- Insufficient or asymmetric impaction/anchorage points in the metaphysis
- Fragmentation or perforation of the bone
- Nail(s) not in the proximal fragment
- Nail(s) not in the distal fragment
- Cork – screw phenomenon
- Failure of one or more points of 3-point contact
- Bending the nail against the cortex at the entry point (unicortical fracture with loss of fixation)
- Over bending of the nail at the entry point (soft tissue irritation, joint stiffness, skin perforation)
- Leaving the external portion of the nail adjacent to the entry point tight on the bone compressing the perichondral ring apophysis risking growth disturbance or induction of a peripheral physeal tether.
- Nail perforation at the proximal femur (nerve injury) [8-10].

The x-ray picture (Figure 5A) below shows the cork screw phenomenon and consequent loss of 3 point contact by both nails, with the nails crossing at the level of the fracture, asymmetric impaction incorrectly (towards each other). The image (Figure 5B) shows different diameter nails (the smaller diameter nail not being in the proximal fragment, the larger having perforated the proximal fragment at the calcar (the tip can irritate the sciatic nerve) with the widest separation of the nails and maximum contact with the cortex being at the wrong level distal to the fracture. These problems are caused by the surgeon [9,11].

Morphology of the Fracture

In children between 13 and 16 years of age the fracture morphology assumes even greater importance as it is in this group that the limitations of the ESIN method are most frequently encountered.

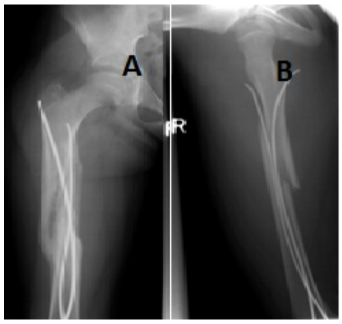

Figure 5: This two x-rays shows the most typical failures with high risk of instability. **(A):** Shows the cork screw phenomenon and consequent loss of 3 point contact by both nails, with the nails crossing at the level of the fracture, asymmetric impaction points for anchorage of the nail tips in the metaphysis of the proximal fragment and the points orientated incorrectly (towards each other). **(B):** Shows different diameter nails (the smaller diameter nail not being in the proximal fragment, the larger having perforated the proximal fragment at the calcar (the tip can irritate the sciatic nerve).

Analysis of the fracture, the patient's normal level of function and potential comorbidities will indicate the optimum method of treatment. For instance teenage polytrauma patients with severe head injury and seizures may require significantly stronger fixation that has to be undertaken rapidly with minimal additional trauma by comparison to the normal child with an isolated femoral fracture sustained in the playground, who will again have differing requirements, to with the osteoporotic child with spastic cerebral palsy [8, 12-14].

Whilst the simple mid-diaphyseal transverse minimally displaced fractures with a canal diameter of 8-9 mm remain the easiest to treat by the ESIN method in this age group when they are less than 170 cm in height and less than 50 Kg in weight a more careful analysis of the following fracture patterns is required before committing to such treatment:

- Long spiral fractures
- Long oblique fractures
- Multifragmentary fractures

Considerations for Optimal Reduction and Stabilization of these Fractures in Adolescence

1. Fixation technique must be adapted to the age, weight, bone morphology and fracture location and associated soft tissue injury.
2. The fixation must be stable and durable in the context of the child's usual level of function.

3. The fixation must be “child friendly” even in adolescence (AVN risk) [15].
4. Reduction must be equivalent to that which would be accepted in an adult as there is no significant remaining modeling potential to correct deformity.
5. The fixation should permit early weight bearing [16].

What are the current options

For the adolescent that demands reduction and fixation of a length unstable diaphyseal femoral fracture, in the absence of significant comorbidity or bony dysmorphism, when the canal diameter is 8-9 mm at the isthmus thereby permitting use of 3.5-4.0 mm diameter elastic nails with intact soft tissues the introduction of “EndCaps” for ESIN has improved the axial stability dramatically [6,7].

An Example of the Use of “EndCaps” in a Length Unstable Fracture Pattern

The use of the EndCaps can improve the axial stability in critical cases. The insertion technique is straightforward (Figures 6A-6C).

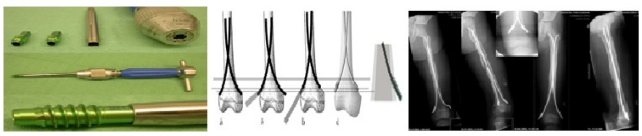

Figure 6: Example of the use of “EndCaps” in a length unstable fracture pattern. **(A):** Only two additional tools were used; screw driver which can be adapted directly on th inserter and the End Cap itself which can be inserted directly because of the self-drilling / self-tapping screw concept. **(B):** Shows graphically the different steps. **(C):** Fixation of a long spiral femoral fracture in a older child, axial stabilized with EndCaps to prevent telescoping.

We do not recommend the use of external fixator for isolated femur fractures in this age group as the reduction and fixation achieved is neither superior quicker, safer, simpler, more stable or less risk in terms of complication than other methods.

When more durable osteosynthesis is required when it might be anticipated that severe soft tissue injury, spasticity/ seizures, poor bone quality or limitation by height and weight or canal diameter or fracture location in the metaphysis means that ESIN is relatively or absolutely contra-indicated then fixation with minimal additional trauma using locked plates inserted following closed reduction by minimally invasive techniques as “internal fixators” technique [16].

For the diaphysis a solid intramedullary interlocked nails is an alternative. The nail should be adapted to the child’s femoral anatomy to take account of the greater sagittal curvature, lower neck shaft angle and avoid the risk of femoral neck fracture at the entry point, induction of growth disturbance resulting in excessive coxa valga or avascular necrosis in the proximal femoral chondro-epiphysis. Due to rapid longitudinal growth of the distal femoral physis in adolescence it is contraindicated to use a distal femoral insertion point nailing system. Therefore we recommend the ALFN, Adolescent Lateral Femoral Nail.

The ALFN

During adolescence the morphology of the femur, means the ratio of the diameter of the medullary canal to the thickness of the cortex is often low. Frequently the canal is no larger than 8 mm to 9 mm (Figure 7A), therefore the normal adult nails are too big and we should probably avoid excessive reaming if possible [5,16,17].

The ALFN is available in the diameter of 8.2mm and 9 mm, is pre-contoured and adapted to the child’s femur (Figures 7B and 7C) and the entry point is on the flat surface on the lateral aspect of the greater trochanter (Figure 7D). In our hands when ESIN cannot be used it is the implant of the first choice.

The figures below show the implant and an example of its use.

Figure 7 (A): The anatomical entry point at the lateral aspect of the greater trochanter.

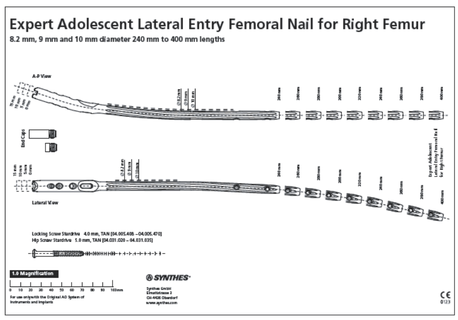

Figure 7 (B): The helical form of the nail and the different length.

Figure 7 (C): The small diameter and again the anatomical adapted nail to the anticurvation of the femur.

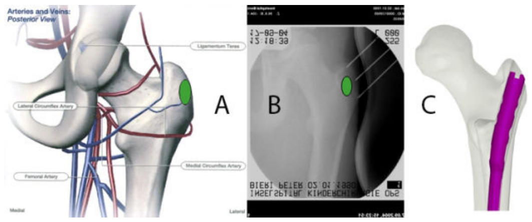

Figure 7 (D): The relation of the entry-point on the lateral aspect of the greater trochanter and the radiological studies.

Example: 15 year old girl, polytrauma, bilateral femoral fractures

Figure 8: Treatment of a 15-years-old girl; polytrauma, bilateral femoral fractures. **(A):** The LODOX x-ray shows a short oblique fracture more in the distal part of the right femur and a comminuted midshaft fracture on the left femur. **(B):** The 3 intraoperative pictures show us the advancement of the nail from the lateral entry-point and the perfect postoperative reduction and stabilization. **(C):** Early and good callus formation on both sides 6 weeks postoperative. Full weight bearing was achieved.

Discussion and Summary

Around puberty there is a great variance in the development of the body and therefore it is important to have an adequate range of methods and implants for the treatment of femur fractures in this age group [18].

We know that when ESIN is not applied correctly this produces avoidable complications. Although truly deleterious outcomes in the long term are rare unfortunately this can encourage a laissez faire attitude towards achievement of surgical excellence with the method. This then denying the patient full benefit of a minimally invasive technique that promotes rapid fracture reduction, pain relief, healing and restoration of function with reduced hospital stay.

Most commonly surgeons struggle with length unstable diaphyseal injury patterns in adolescents and therefore we recommend use of “EndCaps” with ESIN in such fracture patterns in adolescents up to 170 cm in height or 60 Kg in weight as our clinical experience is that the additional stability provided by the EndCaps allows extension of the technique to the heavier child to improve stability particularly when the canal diameter permits use of 3.5 – 4.0 mm diameter elastic nails (8-9 mm canal diameter) or to change to the Adolescent Lateral Femoral Nail or Minimally Invasive Plate Osteosynthesis techniques. It is important that we achieve good quality reduction and high stability with a durable fixation as in this age group we cannot rely on modeling potential and we expect onset of young adult behaviour.

The graphic below shows our concept for the selection of the treatment method in femoral fractures during childhood.

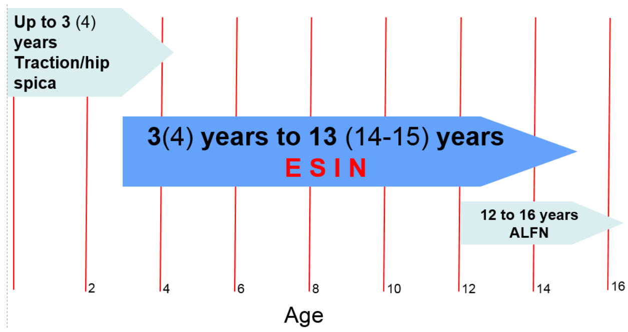

Figure 9: This graphic shows our current and worldwide accepted concept of pediatric femoral fracture treatment; we see that the ESIN Method covers a long period between 3 and 15 years of age [19-21].

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