Managing Pediatric Trauma and Limb Deformity Correction

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How can trauma and limb deformities in children and adolescents be managed successfully?

Femur and tibia fractures are relatively common in children and adolescents. **Alex Trompeter**[1] explaines that injuries are most often **accidental**—e.g. a fall from height, bike or motor accident, mass casualty event—but they can also be **pathologic**, when due to a congenital disease, or **non-accidental (NAI)**, when they do not match with the given explanation. In small children and toddlers, physical abuse is the cause of 12 to 20 percent of all fractures: one third of abuse victims are younger than one year, and half are younger than two. *"The single best predictor or whether or not a pediatric femoral fracture is caused non-accidentally is the child's ability to walk."*
An orthopedist must learn how to recognize an NAI and report young victims of abuse. A skeletal survey may reveal untreated fractures of multiple ages, as well as the presence of posterior rib fractures. These may be signs of abuse as much as metaphyseal corner fractures, with or without soft-tissue injuries.
The expert affirmed that *"bones are genetically engineered to heal and remodel,"* and *"the child's skeleton is extremely forgiving."* **There is more than one valid solution for managing pediatric trauma** and the main objective of a pediatric orthopedic surgeon is to bring each child back to a normal and functional mobility. Intramedullary flexible nails and/or circular hexapod external frames are two different, but both valid, approaches for managing them. The treatment decision is a complex one: *"Do what you are good at"* was the expert's recommendation.

Types of treatments.

When dealing with children, **the simplest** treatment is generally **the best** treatment, but current medical trends consider a number of other factors: age, condition and weight of a child, fracture configuration, experience of the treating surgeon, availability and cost of treatment. **Non-operative** treatment plays a big role in some cases; in others, **operative** treatment is considered more appropriate than a cast if it allows for a quicker recovery and earlier weight bearing and motion. **Compliance by the parent(s) and the child** is considered fundamental during the entire course of treatment, which may last for years in case of severe complicationsA.

Trompeter provides **an algorithm** to support decision-making regarding the management of pediatric diaphyseal femoral fractures[2]:

- for children younger than **6 months**: Pavlik harness or short interval of traction (high suspicion of NAI!) initially
- **6 months to 5 years**: skin traction, in some cases followed by Spica casting, or Spica only
- from **5 to 12 years**: flexible intramedullary nailing or plating with external fixation in the presence of an unstable/comminuted fracture
- **older than 12 years**: under 50 kg, flexible intramedullary nailing, with or without external fixation, or external fixation only, or plating; over 50 kg, locked intramedullary nailing, or external fixation with minimally invasive percutaneous plating (MIPO)

Treating trauma with flexible intramedullary nails.

According to **Jean Damien Metaizeau**[3], three factors may inhibit the choice of Flexible Intramedullary Nails (FIN) in the femur and tibia: **child's excessive weight, instable fractures**, and **too proximal/distal fractures**. A. Trompeter reminds that FIN in heavy children may be a controversial issue; if they weigh more than 50 kg percutaneous plating may be a more appropriate technique. Plating is also preferable to stabilize fractures located too proximally or distally to be managed with FIN.

For the treatment of diaphyseal long-bone fractures, Dr. Metaizeau suggests the following tips and tricks: bend the nail in one plane gently; the diameter should be the biggest possible, at least 40% of the medullary canal; stability relies on the diameter of the nail; keep in mind that the tibia is triangular outside, but inside is circular like the other bones. Very important: when inserted, the two nails should be placed so that the opposing forces are counteracted and eliminated to limit iatrogenic valgus or varus deformities.

Weight bearing depends partly on the child: if he or she does not feel pain after 2 or 3 weeks, then it is allowed. *"Intramedullary nailing limits very often are surgeon's limits!"* was his conclusion.

Limb length discrepancies (LLD) can be congenital or due to acute trauma, infection, tumor, or post-surgical

complications. **Jan Duedal Rölfing**[4] observes that it is more typical in lower extremities, with the tibia and femur most likely affected. The treatment decision for children with LLD is based on not only the growth plate location, the child's age, and extent of the disparity at the time of diagnosis, but also on **predicted increases in discrepancies over time**.

For children with a discrepancy of **about 2-5 cm**, whose bones are still growing, epiphysiodesis may be appropriate. This procedure slows down the growth of the contralateral leg or arm by altering the activity of the growth plate and allows the affected limb to catch up by the end of the growth. The correct timing of the treatment is crucial for the best outcome.

For discrepancies of **more than 3-5 cm**, limb lengthening may be the treatment choice. With experienced orthopedic surgeons, limb lengthening has become a predictable surgical procedure, with an excellent safety profile. Any complications generally involve soft tissues, as they sometimes do not keep up with bone lengthening and provoke contractures.

Radiological and physical examination and a **good program of physiotherapy** can prevent or minimize complications.

Growth guidance.

Elizabeth Moulder[5], **Ignacio Sanpera**[6], and **Jill Flanagan**[7] are prominent surgeons in the guided growth procedure, a term first suggested by P. M. Stevens in 2007 to describe a benign technique with the correction at the deformity apex that takes advantage of the natural ability of the bone to grow in children. Among different methods, the guided growth system—**8Plate+** along with cannulated solid screws—*"is a useful tool as versatile as a metal clip"* sais **E. Moulder**. It has recently gained wide acceptance, as it has proved to work in a more physiological way than other methods.

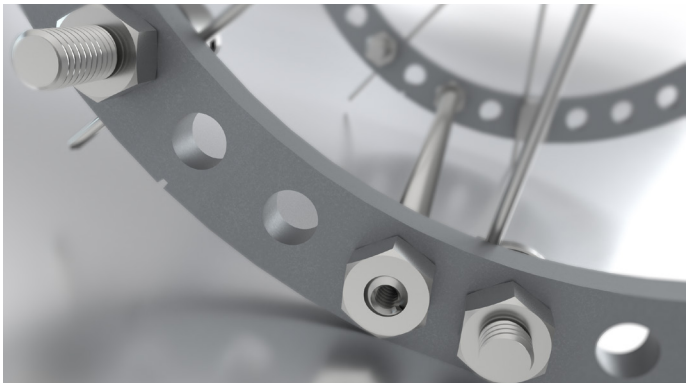
Due to mechanical compression of the physis, bone growth is delayed during skeletal immaturity. This technique gently addresses potential long-range issues regarding angular deformities of the extremities, avoiding complications that may occur with osteotomy. It allows a **quick rehabilitation**, about 2 weeks on average. The downside is that, with guided growth, families should be prepared for multiple surgeries, but at the end of growth the deformity will be none or very small.

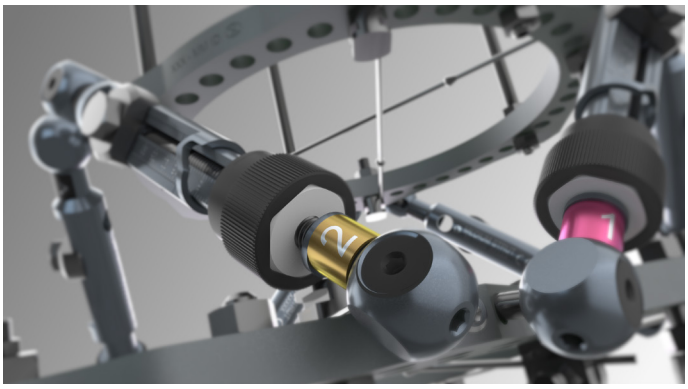
Deformity analysis.

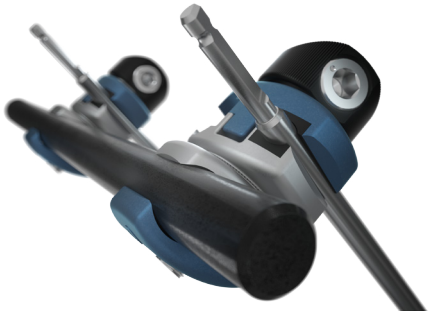
Prof. **Sanpera** reminds of the importance of a correct **deformity analysis**, with a full clinical and radiological examination, and the **assessment of the expectations** of both children and family. He explained that the treatment decision for a child with length discrepancies is based not only on the extent of the disparity at the time of diagnosis, but also on predicted increases in discrepancies over time.
A surgeon should **calculate exactly the amount of deformity to correct** to avoid the risk of overcorrection, malalignment, impingement, and other unsatisfactory outcomes. Instead of following a paper map, digital tools can be used to guide deformity correction like a GPS: specific software systems have been designed to guide surgeons through the treatment to achieve optimal results in an easy way. Orthofix HEX-ray™ and OrthoNext™ are great examples.

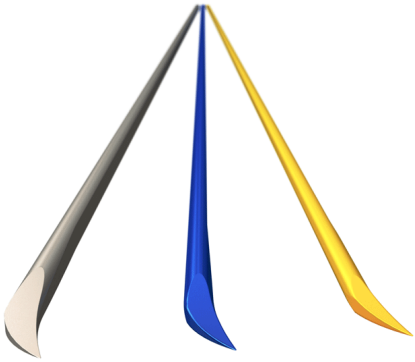
"Chronological age is a poor predictor, as children enter adolescence at different stages," while a **growth spurt** during adolescence is a crucial factor for the growth development. He indicated the **multiplier method** is a very reliable tool: independent of percentile groups, based on a couple of measurements, it allows for a quick calculation of the predicted LLD at skeletal maturity.

Bone deformity correction may be achieved using an **external device** such us an external fixator—circular, hexapod system, pin-to-bar—or an **internal** one, such as an intramedullary nail.









In both cases, a surgeon should always consider the child's bone quality through **three-dimensional parameters: length, alignment**, and **torsion**, and plan accurately the entire correction process.

Deformity correction with computer assisted circular frames.

Franz Birkholtz[8] has wide experience with clinical cases where distraction and gradual correction had been performed with computer assisted hexapod external circular frames, proving to be effective in maintaining segmental alignment and callus formation during lengthening. These devices allow us to understand the **three-dimensional nature of the deformity** (in **varus-valgus malrotation** it plays a big role) and to manage it with gradual adjustments.

It is essential to check **vascular** and **neurological aspects** and **soft tissue** constantly. A supplement of vitamin D may be necessary, with an intensive postoperative program of **physiotherapy** to prevent limb stiffness and contractures.

Dr. **Metaizeau** evidences the advantages of **combining FIN with circular external fixation** for limb reconstruction. This solution may avoid the incidence of secondary deformities after frame removal.

Limb lengthening with an intramedullary lengthening nail.

If this is the chosen option, an effective planning method is the **Reverse Planning Method** (RPM) developed by Prof. **Rainer Baumgart**[9] in 2009. Dr. **Rölfing** considers the RPM a useful method for limb lengthening. When planning in reverse, one starts with the end goal and works backwards from there to develop the operative plan. The RPM is a visual method that shows the surgeon exactly how to proceed to reach the result. In the case of a lower limb length discrepancy, the mechanical axis as well as the bone and joint orientation have to be geometrically measured. Some technical considerations like the **entry point of the nail**, the **diameter of the canal**, the **curvature of the bone**, the **apex of deformity** (if any), the **level of osteotomy**, and the creation of an **adequate bone segment size** to allow for stable locking to the intramedullary nail, should be carefully considered.

Preplanning of any surgical intervention is mandatory, even if the correction to be obtained is moderate and small measurements may seem clinically irrelevant. The final treatment plan must be agreed with the child's family, considering that the child's compliance is also fundamental. **When using hexapod frame systems**, preplanning includes a geometrical analysis of the malalignment, considering the following parameters.

Blount disease *(Tibia Vara)* is a developmental, multifactorial disorder characterized by the abnormal growth of the proximal part of the tibia resulting in progressive lower limb deformity. It seems to include strong **genetic**

and biomechanical components—more patients of African descent, more **obese children**, with overloading of the physis, which disturb growth and produce abnormal ossification of the medial part of the proximal tibial epiphysis and metaphysis. It is common to underestimate the complexity of this disease. The infantile form, occurring in children from 2 to 4 years of age, is generally bilateral and progressive.

Osteotomy is considered **a controversial matter** for children **under 3 years old**. In obese children, the choice to proceed with osteotomy should be accompanied by a complete change of lifestyle for the child, with a proper diet, more exercise, and sometimes some psychological help. Another complex matter is to determine which is the best osteotomy technique to perform.

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