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DIAPHYSEAL FRACTURES OF THE FEMUR IN CHILDREN, SCOPING REVIEW

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ABSTRACT

Introduction: *Fractures of the femur in young ages, both diaphyseal, intertrochanteric and femoral neck, are usually associated with high energy mechanisms. The treatment of femoral diaphysis fractures in children is controversial because the procedures used in adults are not applicable in the growth period.*
Objective: *to detail the current information related to femoral diaphyseal fractures in children, generalities, epidemiology, mechanism of production, physiopathology, characteristics of consolidation, treatment and complications.*
Methodology: *a total of 34 articles were analyzed in this review, including review and original articles, as well as clinical cases, of which 21 bibliographies were used because the other articles were not relevant to this study. The sources of information were PubMed, Google Scholar and Cochrane; the terms used to search for information in Spanish, Portuguese and English were: diaphyseal fractures, femur fractures in children, femur fractures, treatment of fractures in children, child trauma.*
Results: *Femoral diaphysis fractures are more common in males with a 3 to 1 ratio. According to age, 11 percent involve children under 2 years old, 21 percent involve children between 3 to 5 years old, 33 percent between 6-12 years old and 35 percent between 13-18 years old. The incidence of exposed fractures is relatively low, being approximately less than 5%.*
Conclusions: *the management of femur fractures in children is still controversial, so that at present we do not have a general consensus on the ideal treatment, nor is there an effective treatment method that ensures the treatment of all fractures. Each of the various types of treatment has its advantages and disadvantages. The therapeutic alternative chosen will be based on the clinical*

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stability of the affected individual, as well as on the characteristics of the fracture, diameter of the medullary cavity and weight of the individual.

KEY WORDS: *children, fractures, trauma, diaphysis, femur.*

INTRODUCTION

Fractures of the femur in young ages both diaphyseal, intertrochanteric and femoral neck are usually associated with high energy mechanisms. These injuries can generate potentially fatal sequelae, so the correct, rapid intervention and meticulous treatment lead to the best results in affected individuals. Diaphyseal fractures in pediatric patients are usually treated with flexible rods to achieve bone growth. The treatment of femoral shaft fractures in children is controversial because the procedures used in adults are not applicable in the growing period. However, there seems to be some degree of consensus that the method of choice should be aimed at reducing the length of hospital stay, be comfortable for the affected individual, provide proper stability to the fracture and have as few complications and sequelae as possible. It also seems to be unanimous that in children under 5 years of age, conservative methods such as the Pavlik harness and the early plaster cast are the alternatives of choice, unless it is the case of a complex situation or it is contraindicated; after 6 years of age and up to 13 years of age, is the age zone in which the indication of one method or another may be more under discussion, causing more controversy(1-4).

METHODOLOGY

A total of 34 articles were analyzed in this review, including review and original articles, as well as cases and clinical trials, of which 21 bibliographies were used because the information collected was not important enough to be included in this study. The sources of information were Cochrane, PubMed and Google Scholar; the terms used to search for information in Spanish, Portuguese and English were: diaphyseal fractures, femur fractures in children, femur fractures, treatment of fractures in children, child trauma.

The choice of bibliography exposes elements related to femur diaphyseal fractures in children; generalities, epidemiology, mechanism of production, physiopathology, characteristics of consolidation, treatment and complications.

DEVELOPMENT

General

The femur contains the following parts: head, neck, intertrochanteric area, subtrochanteric area, diaphysis, supracondylar and condylar. In this article we focus on diaphyseal fractures in the child.

Epidemiology

Femoral diaphysis fractures are more common in males with a 3 to 1 ratio. According to age, 11 percent involve children under 2 years of age, 21 percent involve children between 3 and 5 years of age, 33 percent between 6-12 years of age and 35 percent between 13-18 years of age. The most common location is at the level of the middle third and transverse trace in about 60%, followed by those that settle in the proximal third with 20%, with those in the distal third being uncommon with 10%. The incidence of exposed fractures is relatively low, being approximately less than 5%(2).

Mechanism of Production.

The most common mechanism of production of femoral diaphysis fractures in children under 3 years of age is casual falls at home or in recreational areas or physical abuse. In older children, they are traffic accidents or accidents in sports or physical activity. There are cases in which the fracture settles on pathological bone due to some other underlying disease such as osteogenesis imperfecta(5).

Pathophysiology

The femur is the largest bone in the human body, along the posterior middle third of the diaphysis, there is an elevated ridge called the linea aspera, which is the insertion site for muscles, fascia and as a strut to offset the anterior arch.

The usual deformity that is generated following a femoral fracture is because of the powerful lower extremity muscles that insert into the femur. The proximal part is held in flexion and abduction, the iliopsoas muscle, which inserts on the lesser trochanter, gives a strong flexion vector. The gluteus medius and gluteus minimus, which insert on the greater trochanter, generate an abduction force. The distal part remains in varus and extension, the adductor muscles insert on the medial femoral condyle and give a force in varus. The gastrocnemius muscle inserts into the posterior distal femoral area, pulling the fragment in a posterior and inferior direction, giving an extension deformity in the fracture(3).

Figure 1. Left femur fracture in an 8-year-old patient with obesity

Source: The Authors.

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Characteristics of Consolidation
The age of the affected individuals gives special characteristics different from those presented in fractured adults:
Rapid consolidation with abundant bone callus.
Phenomenon of hypergrowth of the femur for about 12-18 months post-fracture.
Possibility of spontaneous correction of residual deformities by remodeling phenomena, with the exception of rotational deformities(2).

Treatment
Ideally, it would be the one that allows control of the fracture reduction, besides being comfortable for the child, that presents the least possible psychological impact, that allows easy nursing management, hygiene and does not generate sequelae.

Management will depend on multiple factors, such as weight, age, soft tissue injuries, type of fracture, fracture site, if there are other traumas or other associated fractures. It also depends on the experience of the orthopedist, the hospital conditions and the psychosocial situation.
Treatment can be divided into conservative and surgical.

Conservative Treatment
There are several procedures that will depend on the application of skin or bone traction and its direction with subsequent cast immobilization. In recent times some orthopedists are dispensing with traction time immobilizing the fractured limb with plaster or other devices early.

A. Bryant or Zenith Traction
Properly placed and meticulously monitored, it is indicated in children weighing less than 18kg and under 2 years of age who have a displaced fracture. Avoid in cases of spasticity, hamstring contracture and verify that the hips can flex to 90˚ with the knees in extension. Avoid in individuals with CPI, arthrogryposis and others with decreased hip mobility. Skin traction is exerted on the 2 legs, placing a weight usually around 15-20% of body weight on each leg. Securing the pelvis and trunk of the child to the crib with a modified diaper or sheet is indicated.

In infants, the formation of a bony callus is generated very quickly and 2 or 3 weeks after the trauma the pain disappears and most of the time the fracture will be stable enough to allow the suppression of traction and the placement or not of a pelvic cast for 3 to 4 weeks. The possibility of skin, vascular or neurological complications should be evaluated. Circulatory problems are infrequent. It is important that the circulation, temperature, mobility and sensitivity of the toes are checked periodically. Care should be taken in the placement of the bandages and adhesive traction strips so as not to generate soft tissue lesions(6).

B. Cutaneous or skeletal traction and subsequent pelvic cast
This is considered the treatment of choice for fractures of the femoral diaphysis in children from 2 years of age up to 13 years of age, as it avoids surgical intervention. For this, a soft or skeletal traction is placed in the femoral supracondylar or tibial infratuberosity region. The weight to be placed ranges from 2 to 4kg with the lower extremity resting on pillows or Braun splint. The traction time varies from 2-4 weeks, with weekly radiographic controls for possible shortening, angular deviations and the appearance of periosteal callus that allows us to remove the traction system and immobilize the affected person with a pelvic cast. Sometimes, traction is a provisional treatment method until surgical stabilization of the fracture is programmed, it is preferable to use soft traction because it does not require much analgesia for pain, can be performed without sedation and does not contaminate a possible surgical entry.

Some complications presented with this treatment are angular and rotational deviations and excessive shortening of the fracture, in addition to paralysis of the external popliteal sciatic nerve, difficult management of the polytraumatized patient and poor tolerance during the period of traction and immobilization(7).

There are multiple types of traction that help in control, the so-called 90˚-90˚ skeletal traction that relaxes the calf, hamstring and iliac psoas muscles, due to the 90˚ position of the hip and knee. Despite that, traction should be performed under general anesthesia, using a Steinmann nail or Kirschner wire, these are placed above the adductor tubercle, at the junction of the posterior third and the two anterior thirds of the femoral diaphysis, thus avoiding injury to the growth plate and the suprarrotulian bursa. The nail should be placed perpendicular to the longitudinal axis of the femur. Transtibial traction at the level of the anterior tibial tuberosity should not be used because of the risk of injuring the proximal tibial physis, creating a physeal bridge and an alteration in the recurvatum of the knee(8).

C. Closed reduction and immediate immobilization with bipelvic cast
Recommended in children under 6 years of age. The greatest advantage is the shortening of the hospital stay, however, maintaining the reduction is more difficult and constant control is necessary, which can be done through radiographs, if necessary a correction could be made by means of plaster casts.

Likewise, it is recommended to do it under anesthesia. The estimated time of immobilization in weeks is done by adding "3" to the age of the affected person, so as an example, a 3 year old child should keep the cast for 6 weeks.

The technique has good results. In cases of obesity, edema, shortening and comminution of the fracture site, another method should be chosen because of the difficulty of maintaining the reduction. Some of the complications of the method can be: vicious consolidation, shortening of the affected limb, abrasions, skin ulcers.

There are multiple variations of the method such as early immobilization with pelvipedic cast with hip and knee at 90˚ and rapid immobilization with the Irani technique: immediate reduction, under general anesthesia and simple traction, with immobilization with bilateral pelvipedic cast with the knee flexed between 40-60˚(2,9).

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D.Simple immobilization with Pavlik Harness

Usually used in newborns and infants up to one year of age. The proximal fragment in these fractures usually has a remarkable flexion position due to the physiological flexion attitude of the lower extremities in neonates. Applying the sling brings the distal fragment closer to the proximal fragment in flexion. It is usually immobilized for 4 weeks, the antecurvatum and associated shortening may disappear in the controls due to the strong remodeling capacity. Despite this, it presents inconveniences such as pain during the first days of use when compared to a limb in zenithal traction or in a pelvipedic cast. Fractures in infants from 0 to 18 months can be effectively managed with a Pavlik harness; the herringbone cast is safe and effective in children up to about 6 years of age or 100 pounds(2,10).

Figure 2. Fracture of the left femur after osteosynthesis with plate and screws in an 8-year-old patient with obesity.

Source: The Authors.

Surgical Treatment

Traditionally the indications are:

- Polytrauma.
- Vascular injury.
- Pathological fracture.
- Soft tissue injury.
- Multiple fractures of the same limb.
- Associated brain injury.
- Isolated fracture in which reduction or stabilization is not achieved orthopedically.

The indications have been extended to all open or closed displaced diaphyseal fractures in children older than 5 years due to the high rate of malunions, long hospital stay, increased cost, among others.Cruel treatment has some advantages such as reaching an anatomical reduction and/or stabilization of the fracture, with lower rate or without axial and rotational deviations(9,11,12).

A. Screw-In Plates

Used for decades with excellent immediate results. The need for an open reduction and a second intervention for the removal of the material can generate excessive femoral hypergrowth, up to 4cm (13).

A good indication for this method of osteosynthesis is subtrochanteric fractures, which are difficult to manage with orthopedic methods. Currently, AO plates have gained popularity due to their percutaneous application; at the moment there are no long-term studies on hypergrowth with this technique(14).

B. Rigid intramedullary nail with or without locking

The use of the rigid intramedullary nail began to be placed in children after the promising results in adults with Kuntscher nails. It presents excellent immediate results and does not require the opening of the fracture site, however, there are studies that show that the entry of the nail through the tip of the greater trochanter or the piriform fossa generates significant changes in the growth of the proximal femur and risk of necrosis of the femoral head, so it is generally recommended in individuals close to or having already completed growth. There are new models of nails, however, long-term results with evidence of injury to the trochanterocervical growth plate of the proximal femur are not yet available(2,15-17).

C. Elastic Intramedullary Nailing

Used as the method of choice for the treatment of displaced diaphyseal fractures in children. It is performed with titanium or steel nails of multiple calibers depending on the diameter of the diaphyseal medullary cavity with diameters between 2-4mm. In adolescents, 3-4mm nails can usually be used, according to weight, diameter of the medullary cavity and growth remnant. Between 7 and 10 years of age, 2.5-3mm nails can be used. The formula to be used is usually to measure the diameter of the medullary cavity and multiply it by 0.4 with the objective of occupying 80% of the medullary space in the medial femoral 1/3. The larger diameter of the elastic nail confers greater resistance to deformation of the fracture site under axial compression and torsion(18).

The nails are introduced at a distance from the fracture site, respecting the physes. By bilateral retrograde supracondylar route in fractures of the middle and upper third, or external subtrochanteric in low fractures. The nails have a curved shape and provide three-point support in the bone, giving elastic stability. Normally the limb is left in unloading for 2-3 weeks, partial loading at the sixth week and according to radiological controls. Studies show good results in transverse or short oblique fractures in the middle third of the diaphysis. In comminuted fractures or fractures with great instability, elastic intramedullary synthesis may not be sufficient. Subtrochanteric fractures and distal metaphyseal-diaphyseal fractures are not a good indication to use this method, as well as adolescents with

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a medullary cavity greater than 10mm or weight greater than 50kg(19,20).

The most common disadvantage of elastic intramedullary nailing is discomfort in the knee, due to the fact that sometimes the nails exceed a few centimeters to facilitate extraction. The advantages of this method are: easy application, low risk of infection, non-interference of the fracture site, no fissure aggression, fast consolidation. There is an advantage of steel nails compared to titanium nails. The greater rigidity of steel provides greater stability with fewer vicious consolidations(2).

D. External Fixation

It presents common indications such as: polytrauma, open diaphyseal fractures, comminuted, with loss of bone substance and some pathological fractures. In distal metaphyseal-diaphyseal fractures, a fixator temporarily bridging the physis stabilizes and controls the fracture until healing. Modular monolateral systems that allow different configurations and with an intrinsic resistance that provides stability until healing are recommended. In the supracondylar region, sometimes, the placement of needle-mounted rings can provide an appropriate setup in fractures with intercondylar trace or with a distal comminution that does not allow the insertion of 5-6mm screws used in the usual monolateral external fixation.

The type of screw to be used should be 5-6mm, except in small children with femoral diaphyseal diameter of less than 2cm, where 4-5mm is recommended.the use of high speed motors (< 500rpm) should be avoided, due to the risk of thermal necrosis and secondary osteolysis.to reduce the incidence of osteolysis around the screw, self-drilling screws or screws with hydroxyapatite coating are used. The use of 6 screws at the femoral level is recommended if possible. When there is radiological evidence of consolidation, greater support is allowed. Unlike adults, conversion from external to internal fixation is not usually necessary in children, since consolidation times are faster. One of the complications seen is refracture after removal of the external fixator, also infection around the screws, axial deviations and hypergrowth phenomenon. Knee stiffness usually disappears 3 months after removal of the external fixation device(2,21).

Complications

Early Complications

- **Thromboembolism:** rare, may occur in the pubertal period and in predisposed individuals with antithrombin III deficiency.
- **Fat embolism:** in the first 72 hours after fracture, unusual in children under 10 years of age.
- **Hypovolemic shock:** in polytrauma.
- Infection: in exposed fracture with soft tissue injury, in opening of the focus to reduce the fracture.
- **Osteomyelitis:** adversely affects the hypergrowth of the extremity.

Late Complications.

They occur along the consolidation process or in the subsequent evolution, they are influenced by the characteristics of the fracture, in addition to the injured individual and by the chosen treatment. Some of these are:

- Refracture.
- Discrepancy in the length of the limbs.
- Delay of consolidation or pseudoarthrosis.
- Rotational deformity.
- Axial deviations.
- Premature fissure closure.
- Sciatic nerve injury.

CONCLUSIONS

The management of femur fractures in children is still controversial, so that at present there is no general consensus on the ideal treatment, nor is there an effective treatment method that ensures the treatment of all fractures. Each of the various types of treatment has its advantages and disadvantages. The therapeutic alternative chosen will be based on the clinical stability of the affected individual, as well as on the characteristics of the fracture, diameter of the medullary cavity and weight of the individual.

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