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G. Chapchal, Luzern

Symposium on Fractures in Children, Nijmegen, April 14, 1978

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Contents

Introduction

Treating fractures in children is working with living material. So astonishing as may be the possibility to spontaneous correction of deformities in some cases, so frustrating may be the occurrence of late deformities in maltreatment. The crucial point in the laborious treatment of fractures in children is the acknowledgement of the special properties of the growing bone. In this symposion, organized for general and orthopaedic surgeons in the Catholic University Nijmegen, Holland, on April 14, 1978, we tried to define some principles and guidelines for this treatment. Besides the general introductions in the several topics, there was free discussion about several aspects of fracture treatment in children on behalf of personal experiences, from which several were selected for this publication.

We thank the editors of the *Journal of Reconstructive Surgery and Traumatology* and especially Prof. *Chapchal*, for the opportunity to publish this symposion.

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Children's Fractures: Principles and Management

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Introduction

Children's fractures are unlike adult fractures and require distinctive methods of management. There are anatomical, biomechanical and physiological differences between an immature growing skeleton as compared with mature adult bone. In this article we will discuss the general features of children's fractures and offer guidelines for their effective management.

Anatomical and Biomechanical Differences

Bone Structure

A child's bone is more flexible because young bone is more porous with Haversian canals that are larger than adult bone [6] (fig. 1). This porosity accounts for the three major biomechanical differences in children's bone and produces the different fracture types. Porosity allows a greater degree of plastic deformation to occur prior to fracture, thus more flexibility; it limits the propagation of fracture by relieving stress concentration; and it allows a child's bone to fail in both compression and tension. Adult bone fails only in tension.

The various fracture types seen in children are: torus, bend, greenstick and complete (fig. 2). The torus fracture represents a compression failure of cortical bone and thus produces the typical buckle deformity. These generally occur near the metaphysis where the porosity is greatest and the bone the weakest. Bending of bone is a result of marked plastic deformation with a resultant permanent deformation. This is most commonly seen in the ulna

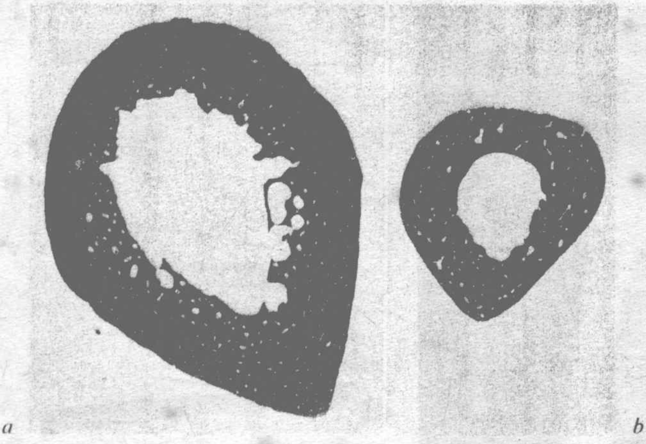


Fig. 1. Cross section microradiograph of a distal radial diaphysis of an adult (a) and an 8-year-old child (b). Note the larger Haversian canals and increased porosity.

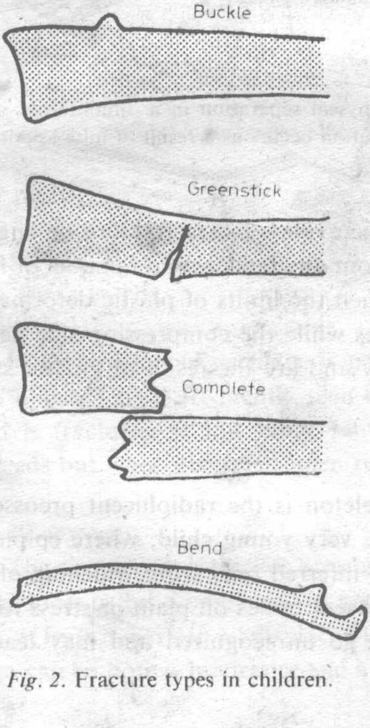


Fig. 2. Fracture types in children.

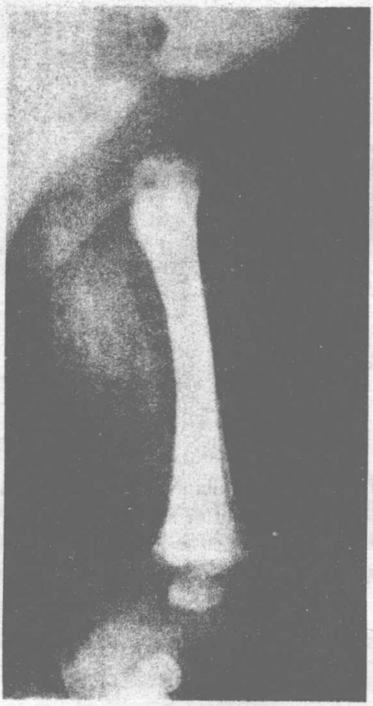


Fig. 3. Undisplaced distal femoral epiphyseal separation in a 3-month-old infant 2 weeks postinjury. Subperiosteal callus formation occurs as a result of initial periosteal elevation.

and fibula and there is no radiographic evidence of a fracture or angular deformity. The bend is permanent without any tendency to remodel or form callus. Greenstick fractures develop when the limits of plastic deformation are exceeded. The tension side fractures while the compression side bends. Complete fractures are self-explanatory and are the result of greater stress or energy absorption.

Cartilage

A significant part of a child's skeleton is the radiolucent preosseous growth cartilage. In the infant and the very young child, where epiphyses may still be unossified, injuries can be inferred only from widening of the growth plate or by displacement of adjacent bones on plain or stress radiographs (fig. 3). Some of these injuries go unrecognized and may lead to serious problems later.

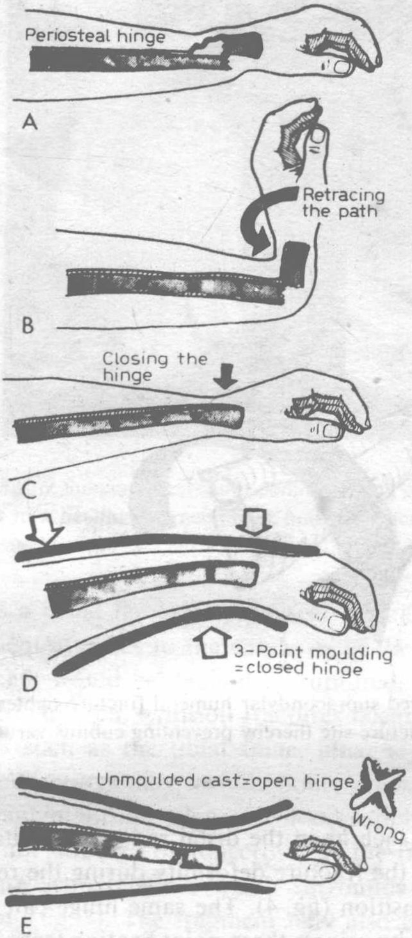


Fig. 4. Bohler technique of fracture reduction.

When preosseous cartilage is partially avulsed it may remain attached by a hinge. This is frequently seen in tibial spine and lateral humeral epicondyle fractures. If this hinge remains intact closed reduction generally succeeds but when disrupted open reduction is usually necessary.

Periosteum

The periosteum is thicker, stronger and more osteoblastic than in adults. It produces callus quickly and in greater amounts. The periosteum must be torn, at least in part, in all displaced fractures. The remaining thick periosteal hinge can be both a hindrance and a help in fracture treatment. It can hinder

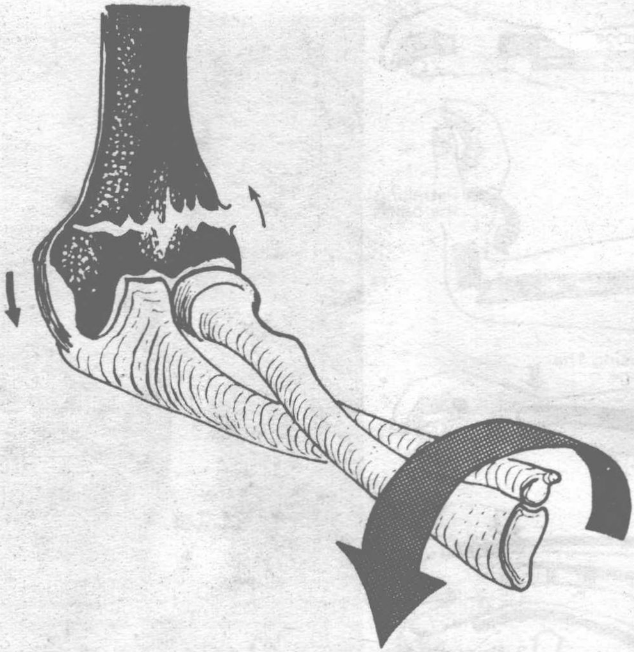


Fig. 5. Pronating a medially displaced supracondylar humeral fracture tightens the medial periosteal hinge and closes the fracture site thereby preventing cubitus varus.

reduction in overlapping fractures such as in the distal radius necessitating the Bohler maneuver of increasing the fracture deformity during the reduction to allow cortex-to-cortex apposition (fig. 4). The same hinge can then stabilize the fracture after reduction by using a three-point fixation technique. In supracondylar fractures of the elbow, the presence of medial or lateral periosteal hinges can be used to stabilize the fracture site [1] (fig. 5). Pronating fractures with medial displacement or supinating those laterally displaced will tighten the hinge and close the fracture site thereby preventing the development of cubitus varus or valgus (fig. 6).

Ligaments

Children's ligaments are stronger than both the bone to which they are attached and their associated growth plates. This accounts for the scarcity of ligamentous injuries in children and the frequent occurrence of epiphyseal separation and fractures. A severe valgus stress to the knee of a child pro-

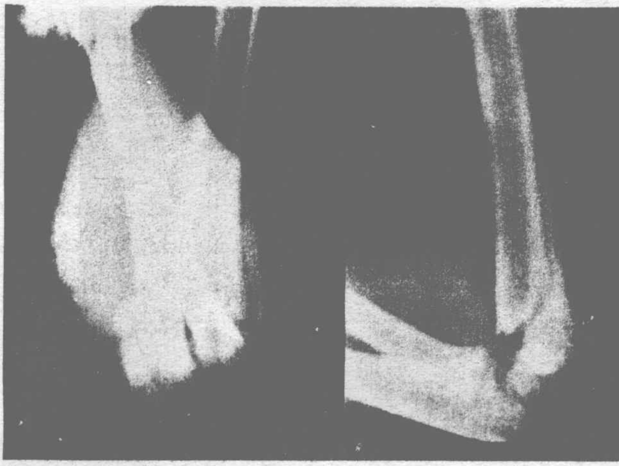


Fig. 6. Subperiosteal callus demonstrating presence of posterior and lateral periosteal hinges in a healing supracondylar humeral fracture.

duces a distal femoral epiphyseal separation because the medial collateral ligament attaches to the epiphysis of the femur. In the adult, however, the ligament would be avulsed or ruptured.

In children, avulsion fractures occur at the site of ligamentous attachments such as the tibial spine, ulnar styloid and the bases of phalanges. These fractures may include bone, preosseous cartilage or both. The fragment maintains an adequate blood supply from the ligament and therefore does not undergo osteonecrosis. If the fracture is displaced, union is rare, because synovial fluid which surrounds the fragment inhibits callus formation (fig. 7). The fragment may also block joint movement or leave the joint unstable because of functional ligamentous lengthening. Accurate reduction is mandatory in these injuries and generally open reduction and internal fixation is required.

Epiphyseal Growth Plate

Injuries to the epiphyseal growth plate are common in children and have potentially serious consequences if not properly managed. The strength of the plate comes from the plate itself, the perichondral ring and the interdigitating mammillary processes. The hormonal environment also effects the strength of the plate [5]. When separation occurs it passes preferentially through the zone of chondrocyte hypertrophy. This is the area with least

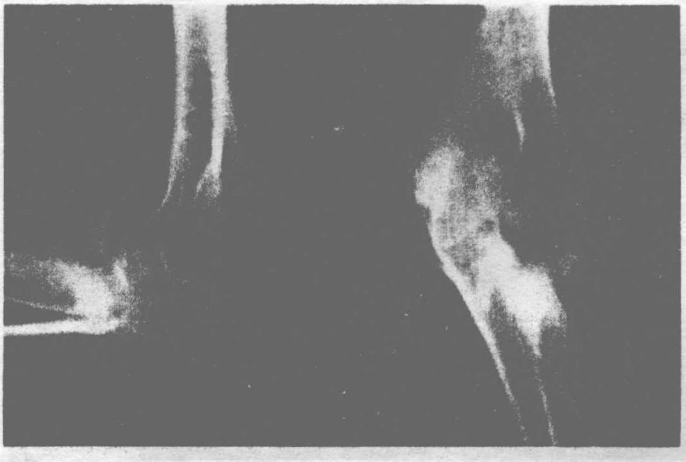


Fig. 7. Nonunion of intra-articular radial neck fracture in a 15-year-old male. Synovial fluid in the fracture site inhibits callus formation.

matrix and is therefore the weakest. *Bright and Elmore* [2] found the plate to be most resistant to traction and least resistant to torsion (fig. 8). Furthermore, the plate could be displaced 0.5 mm before separation occurs.

The seriousness of a growth plate injury depends on several factors. These are: (1) the type of epiphysis involved; (2) the amount of remaining growth; (3) the type of injury; (4) the method of treatment and (5) the presence or absence of infection.

Injury to epiphyses totally clad in cartilage such as the head of the femur and radius may disrupt the epiphyseal blood supply thereby producing osteonecrosis and an arrest of longitudinal bone growth. The blood supply to epiphyses with soft-tissue attachments generally is preserved and osteonecrosis, therefore, does not occur.

The Salter-Harris classification of epiphyseal injuries offers the most practical guide in dealing with these injuries [12] (fig. 9). Prognosis is generally dependent on the type of injury. Generally type I and II lesions can be managed by closed reduction and although anatomical alignment is desirable it may be unnecessary since remodelling will occur. Displaced type III and IV lesions are intra-articular and require accurate alignment generally by open reduction and internal fixation. Type V or crush injuries have the worst prognosis but can be diagnosed only in retrospect.

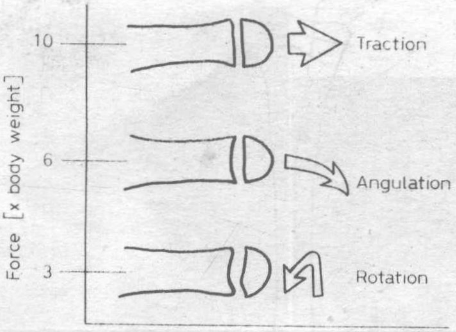


Fig. 8. Force required to separate the growth plate depends upon the direction of the applied stress. After *Bright and Elmore* [2].

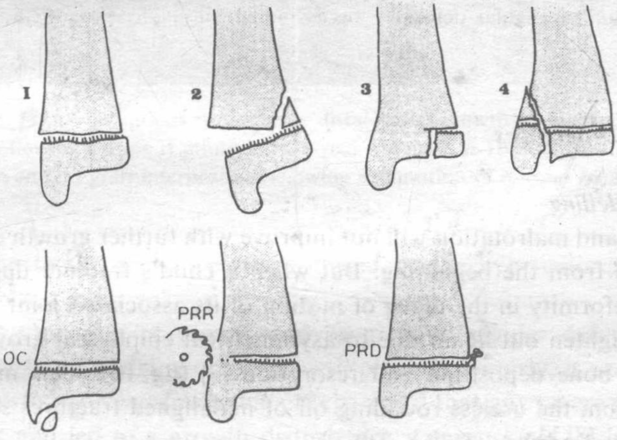


Fig. 9. Types of growth plate and perichondral ring injuries. OC = Osteochondral fracture; PRR = perichondral ring removal; PRD = perichondral ring displacement.

Perichondral Ring

The perichondral ring encircles the growth plate and appears to regulate its diameter and circumference [13]. Injuries to this ring are rare but produce characteristic lesions. Displacement will produce a traumatic exostosis whereas removal of the ring, generally by an abrasive or scalping injury, causes a bony bridge to form between the epiphysis and metaphysis that can lead to progressive angular deformity (fig. 9). These partial plate closures are best handled by resection and interposition of either fat or silicone rubber implants [3, 8].

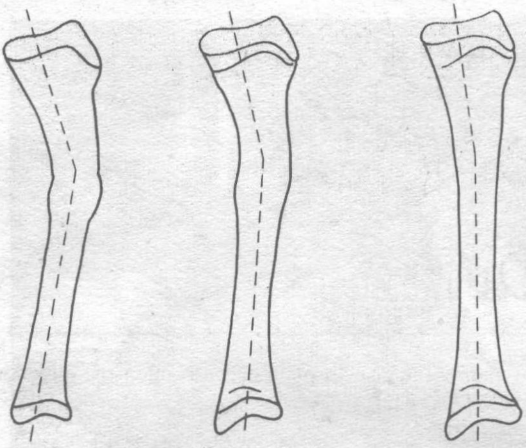


Fig. 10. Correction of angular deformity by asymmetrical epiphyseal growth.

Physiological Differences

Growth Remodelling

Varus, valgus and malrotation will not improve with further growth and must be prevented from the beginning. But when a child's fracture unites with an angular deformity in the plane of motion of its associated joint the bones tend to straighten out again due to asymmetrical epiphyseal growth and by periosteal bone deposition and resorption [7] (fig. 10). This must be distinguished from the useless rounding off of malaligned fractures seen in older children and adults.

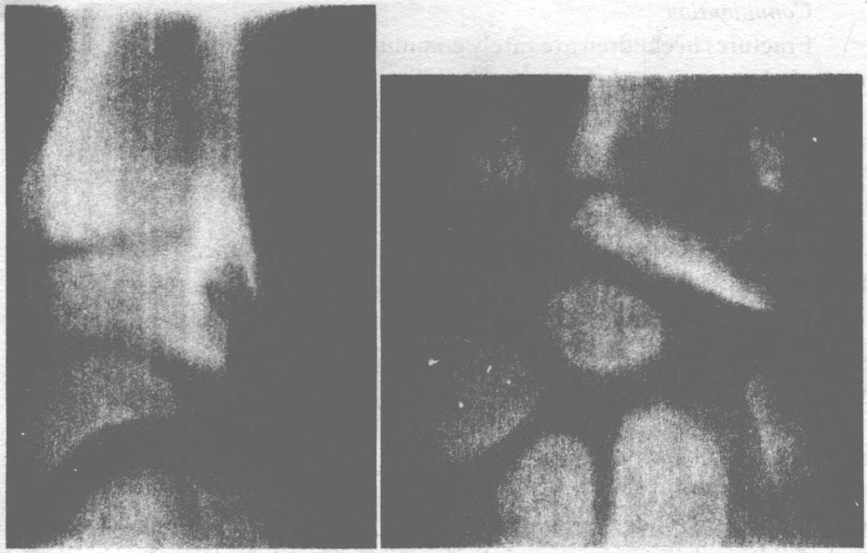
Joint Stiffness

Stiffness is rare in uninjured joints despite prolonged immobilization. This, presumably, is due to their somewhat lax ligaments and joint capsules, plus their rapid return to full activities despite parental attempts to the contrary. Injured joints, however, should be moved early to avoid stiffness and promote healing.

Growth Disturbances

Disturbances of growth can be manifested in two distinct ways:

(1) Growth may be accelerated. Diaphyseal or metaphyseal fractures of long bones stimulate longitudinal growth, probably because of increased



a b

Fig. 11. a Tomograms through the distal radial growth plate demonstrating a bony bridge following a Type II injury in an 8-year-old male. *b* Tomogram 6 months following resection and fat graft interposition showing resumption of normal growth.

nutrition to the growth plate produced by the hyperemia associated with fracture healing.

(2) Cessation of growth and progressive angular deformities are the result of bony bridging of the growth plate. Previously, it was thought that the growth plate was incapable of repair and that any severe injury was permanent and led to a growth disturbance. *Langenskiold* [8] has shown that the growth plate closes only when restitution of cartilaginous continuity is prevented by the intrusion of a bony bridge. Excision of the bony bridge will allow further growth and remodelling to occur (fig. 11).

Progressive rotational deformities are limited to the spine, where scoliosis can result from an injury of the vertebral epiphyses.

Rate of Healing

Children's fractures heal much more quickly than adults'. The rate of healing is related to growth rate. Younger children heal faster. Reduction must be obtained early and the child observed closely to ensure that a fracture does not heal before it is reduced. Malpositioned diaphyseal fractures of the radius and ulna seen to unite particularly fast.