FRACTURE BOTH BONES FOREARM IN CHILDREN

Injuries to the shafts of the **radius** and ulna are the most common injury. Because of numerous differences in both treatment and prognosis, shaft fractures are considered to be clinically distinct from fractures of the metaphysis.

Bohler: "steady (not jerky) strong traction by pulling on the thumb with one hand and on the second to fourth fingers with the other hand. Traction on the thumb must be stronger than that on the other fingers". **Fracture** reduction techniques for complete fractures from Böhler's original textbook. **A.** Longitudinal traction method. **B.** Exaggeration of deformity method.

Charnley did not accept Böhler's concept of skin-tight plasters and favored padded plasters with three-point molding instead. This concept was embodied by Charnley's maxim: "A curved plaster is necessary in order to make a straight limb.

Blount (1900-1992), in his book on children's fractures, offered strong recommendations for nonoperative treatment of nearly all children's fractures. Regarding forearm fractures in children Blount also stated, "Bayonet apposition in good alignment is not to be confused with angular deformity.

Rang highlighted many of the practical aspects of caring for children's fractures, including forearm fractures. Contrary to the forearm shaft **fracture** rotational dogma of others, Rang said, "Immobilize the **fracture** in the position—any position [rotation]—in which the alignment is correct and the reduction feels stable. He also discussed the value of single-bone internal fixation with a Kirschner wire in selected patients when open reduction was preferable to malunion.

EPIDEMIOLOGY

Males who are 13 years at risk.

Associated with backyard trampoline

Large studies:

I Commonest **distal** radial

II Supracondylar humeral fractures

III Forearm shaft fractures [III most common **fracture** of childhood]

Among pediatric fractures, forearm shaft injuries are the most common site of refracture.

Types of forearm fracture

I. Fracture Both bones: Location:

[Blount's #]	- distal 1/3 :	75%
	- middle 1/3 :	18%
	- proximal 1/3:	7%

II Fractures of Radius: with no instability of DRUJ

with instability of DRUJ [Galeazzi's]

III Fracture of Ulna: with no instability of radial head

with instability of radial head [Monteggia]

PRINCIPLES OF MANAGEMENT

Mechanism of Injury

1. Fall on an outstretched hand that transmits indirect force to the bones of the forearm.
2. If the radial and ulnar fractures are near the same level, a minimal torsional component can be inferred and is usually due to direct impact.
3. If comminution is present, higher-energy trauma should be suspected.
4. Significant hyperpronation forces are associated with isolated shaft fractures of either the **radius** or the ulna and concomitant dislocation [Galeazzi and Monteggia **fracture**-dislocations]
5. Isolated ulnar shaft fractures have been referred to as "nightstick fractures.

Rang referred to apex volar greenstick fractures of the **distal** radial shaft near the metaphysis as "the slipper" because of its annoying tendency to lose position after otherwise satisfactory reduction.

Remodeling

Blount's original work showing dramatic
remodeling. **A.** Six-year-old male with both-bone forearm **fracture**.
B. Six months after injury. Comparison of AP **(C)** and lateral **(D)** radiographs
of both forearms at 5-years follow-up.

Remodeling: 1°/month or 10° per yea

Clinical features

The mechanisms of injury of two particular forearm **fracture** patterns, traumatic bowing (also known as bow fractures or plastic deformation) and greenstick **fracture**, also bear mentioning.

Thus, when a bending force is applied relatively slowly, many micro fractures occur along the length of the bone, leading to macroscopic deformity without discernible radiographic **fracture**. This bending can usually be seen on an X ray.

Greenstick fractures represent an intermediate step between plastic deformation and complete fractures.

As a general rule, a **fracture** should be suspected if the child has not resumed all normal arm function within 1 or 2 days of injury.

The so-called floating elbow injury (**fracture** of the bones of the forearm along with ipsilateral supracondylar humeral **fracture**) is a well-described entity that must not be missed.

Galeazzi and Monteggia **fracture**-dislocations also must be ruled out by assessing proximal and distal radioulnar joints.

Compartment syndrome also can occur in conjunction with any forearm shaft **fracture**. This rare but potentially devastating complication can lead to a Volkmann ischemic contracture should be avoided.

For all practical purposes, the buckle **fracture** pattern that is common in the **distal** radial metaphysis never occurs in isolation in the shaft region.

Certain situations may raise concern regarding complete translation, such as isolated middle-third radial fractures with medial (ulnar) displacement that significantly narrows the interosseous space and translation in children who have less than 2 full years of growth remaining, because remodeling of the translated **fracture** site is less predictable than in younger children.

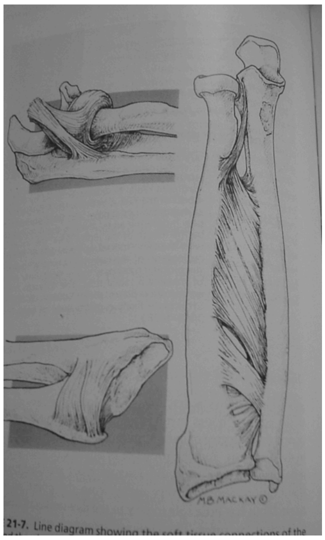
Several generations of orthopedic surgeons have been taught that 50 degrees of pronation and 50 degrees of supination represent adequate forearm motion. Morrey study 68 degrees pronation to 74 degrees supination.

SURGICAL AND APPLIED ANATOMY

The forearm is a large nonsynovial joint with nearly a 180-degree arc of motion.

Ossification centers

Distal radius 1 year of age.
Proximal **radius** 4-6
Distal ulna 4-6 years of age.
Proximal ulna 9 years



Physeal closure

Proximal 15 years of age
Distal R & U 18 years of age.

Radius and ulna connected by : 2 Pronators and 1 supinator

- **# Proximal 1/3** Proximal fragment supinated
- **# middle 1/3** Proximal fragment is neutral
- **# Distal 1/3** Proximal fragment is pronated

Interosseous membrane: 3.5 cm in width

POP depending on different sites of fracture ha not been favored. Neutral position is the best position.

Hotchkiss showed that the central band of the Interosseous membrane (the interosseous ligament) courses from a point near the junction of the proximal and middle thirds of the **radius** to a point near the junction of the middle and **distal** thirds of the ulna. It is an important longitudinal stabilizer of the forearm in that 71% of forearm longitudinal the interosseous ligament provides stiffness after radial head excision.

Common Surgical Approaches

The Henry (anterior) and Thompson (posterior) approaches to the radial shaft

The direct (medial) approach to the ulnar shaft.(Boyd)

CURRENT CLOSED TREATMENT OPTIONS

Undisplaced fractures of the distal third of the radius in children [Injury 23: 165]

23% of fracture with dorsal angulation progressed; none in the volar angulation

13% unicortical and 48% bicortical progressed.

7% buckle progressed

Needs X ray at one week to rule out displacement

Displaced fracture

Most pediatric radial and ulnar shaft fractures can be treated by nonoperative methods. Low-energy, undisplaced, and minimally displaced forearm fractures can be immediately immobilized in a properly molded (three-point mold concept of Charnley) above-elbow cast. If posttraumatic tissue swelling is a concern, noncircumferential splint immobilization (e.g., sugar tong splint) can be used initially. For fractures in the **distal** third of the forearm, below-elbow casting has been shown to be as effective as above-elbow casting in maintenance of satisfactory **fracture** alignment. Appropriate follow-up is important for these undisplaced fractures (an initial follow-up radiograph usually is taken 7 to 14 days after injury) because displacement may still occur for a variety of reasons: new trauma to the extremity, male gender, and poor casting technique.

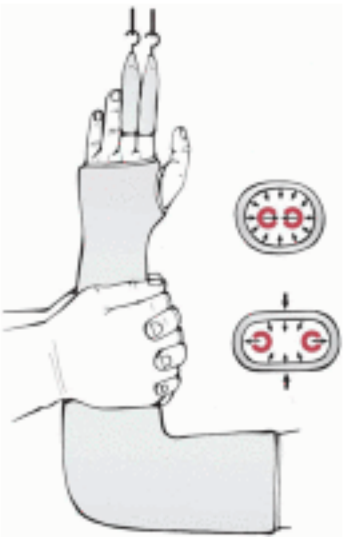


FIGURE 10-22 Interosseous mold technique.

View Figure

The principles of good forearm casting technique include: (a) interosseous molding, (b) supracondylar molding, (c) appropriate padding, (d) evenly distributed cast material, (e) straight ulnar border, and (f) three-point molding. The cast index for **distal** radial fractures defined as the sagittal cast width divided by the coronal cast width at the level of the **fracture** site; a normal ratio is considered to be 0.70. The cast index has not been validated for forearm shaft fractures.
Ketamine protocols also are being used with increased frequency.

Traumatic Bowing/Plastic Deformation

Borden's classic paper in 1974 reported that bow fractures show no obvious macroscopic **fracture** line or cortical discontinuity, but they do demonstrate multiple microfractures (slip lines) along the length of the bow. At times, a nearly classic buckle **fracture** (torus **fracture**) coexists with a bow **fracture**. The most common clinical scenario is a plastically deformed ulna along with a more typical **fracture** of the **radius**.
Borden and subsequent authors stressed the importance of natural remodeling potential in these injuries but voiced concern about this approach in older children (especially those over 10 years of age). Traumatic bowing that causes cosmetically or functionally unacceptable angular deformity must be manipulated under general anesthesia or deep sedation because strong (20 to 30 kg) gradual force applied over 2 to 3 minutes is required to obtain acceptable alignment. Application of this reductive pressure over a rolled towel, block, or surgeon's knee fulcrum followed by a three-point molded cast can substantially (although at times still incompletely) correct the deformity.

Greenstick Fractures

Greenstick fractures present special issues in terms of diagnosis and treatment. Angulated greenstick fractures of the shafts of the **radius** and ulna at different levels indicate a significant rotational component to the injury. Often, the apparent angular deformity can be corrected by simply reversing the forearm rotational forces (e.g., reducing an apex-dorsal pronation-type injury with supination).

It is noted that most greenstick fractures are supination injuries with apex-volar angulation and thus can be reduced by a pronation movement. Greenstick fractures that occur near the same level probably have little to no rotational component and are best corrected by manipulative reduction and three-point molding techniques. Despite these concerns, it is clear from large published reports that greenstick fractures can almost always be successfully treated with nonoperative methods.
Two philosophies are reflected in the literature regarding greenstick **fracture** reduction: one in which the greenstick **fracture** is purposely completed and another in which it is not. Those who favor completing the **fracture** cite concerns about lost reduction and recurrent deformity that can be prevented only by converting the greenstick into a complete **fracture**. Others prefer to maintain and

perhaps exploit some of the inherent stability of the greenstick **fracture**. In addition to the traditional view that loss of reduction is less likely if a greenstick **fracture** is completed, there also is the theoretical advantage of a lower refracture rate because of more exuberant callus formation. To the best of our knowledge, these theories have not been validated in any controlled clinical studies.
In a prospective study, Boyer showed statistically that greenstick fractures maintain their reduction better than complete forearm fractures.

Complete Fractures [Position in the cast]
Theoretically, the position of forearm rotation in an above-elbow cast or splint affects rotational alignment of complete fractures at all levels; however, a study of **distal**-third forearm fractures found no significant effect of forearm rotation position on ultimate alignment.
The position of immobilization of fractures in the middle third of the forearm commonly is dictated by whether the radial **fracture** occurs **distal** or proximal to the insertion of the pronator teres. Fractures proximal to its insertion are best treated by fully supinating the **distal** fragment, while those **distal** to its insertion are probably best treated in a neutral position.

CURRENT SURGICAL TREATMENT OPTIONS
A more than 10-fold increase in the rate of operative treatment of forearm shaft fractures in children, but it is unclear as to whether this increase in operative treatment has led to a commensurate improvement in clinical outcomes.

Operative treatments of radial and ulnar shaft fractures usually are reserved for open fractures, those associated with compartment syndrome, floating elbow injuries, and fractures that develop unacceptable displacement during nonoperative management.

Closed Reduction
Informed consent
Under IV ketamine and midazolam
Reductions are done under image intensifier
The initial position of forearm rotation is based on the level of the **fracture**, and the final position is based on the best reduction under fluoroscopy.
Casting technique:
Cotton padding; above elbow cast with 3 point fixation.
If swelling makes the splint too tight split the plaster and elevate with a sling.
Patients are given discharge instructions and a prescription for mild narcotic analgesics.
Major re-manipulations are best done with general anesthesia.
By the **end** of the fourth week after injury, many above-elbow casts can be converted to below-elbow casts.
Adequate **fracture** healing should be confirmed by radiographic and physical examination before unlimited athletic participation.

Acceptable Limits of Angulation

a. Site of fracture

Distal third < 20° of angulation

Midshaft <15° for both bones [20° loss of angulation, 50° of rotational movement [JBJS 1982: 64: 14]

Proximal < 10°

Accept 100% translation if shortening is less than 1 cm.

Closer the growth plate better is the remodeling

b. Age: Younger the patient better is remodeling. Angulation less than stated above is acceptable provided the child has at least 2 years of growth is remaining.

Both bones forearm: Acceptable angle < 10°

>10° = over 8 years not acceptable

>20° = 50% loss of rotation

Wrist fractures:

Wrist injuries: <30° in <8 years

<20° in > 8 years

Remodel in both dorsal and radially angulation: 1° per month

d. Complete or plastic: Plastic deformation fractures seem to have less remodeling potential than other fractures, and radiographically or cosmetically unacceptable angulation may require gradual, forceful manipulation under sedation or general anesthesia.

Surgical Treatment

Plate Fixation

Indications: Unstable fractures, malunion, open fracture

Dynamic compression plates and one-third tubular plates are commonly employed.

Six cortices above and below the **fracture** site obtained good results.

Plate fixation may allow more anatomic and stable correction of rotational and angular abnormalities and restoration of the radial bow than with noncontoured intramedullary rods; however, the larger incisions and extensive surgical exposures required for plate fixation have raised concerns regarding unsightly scars.

Elastic Stable Intramedullary Nailing

In the early 1980s, Metaizeau described elastic stable intramedullary nailing (ESIN) of pediatric forearm fractures

The prebent flexible rods (known as Nancy nails) were reported to maintain satisfactory **fracture** alignment while encouraging development of normal physiologic **fracture** callus.

Biomechanically, these implants have been shown to act as internal splints provided the nails extend three or more diameters beyond the **fracture** site

Management of Open Fractures

Early irrigation and debridement

Available internal fixation methods

More commonly require internal fixation.

The “ruffled border sign” may be an early sign of osteomyelitis.

The infection rate ranges from 0% to 33%.

If surgical treatment is deemed necessary, intramedullary fixation is preferred over plate fixation because of reduced soft tissue disruption. Occasionally fix one bone when both bones are fractured if overall forearm alignment is acceptable and stable after single-bone fixation. Fracture radius or ulna with disruption of proximal and distal radio-ulnar joint requires surgery. Segmental, open or pathological fractures need surgical stabilization.

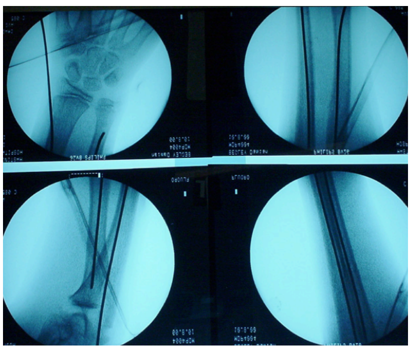
If single-bone fixation is done, the ulna usually is treated first because of its more benign entry site, subcutaneous location, and relatively straight canal compared to the **radius**.

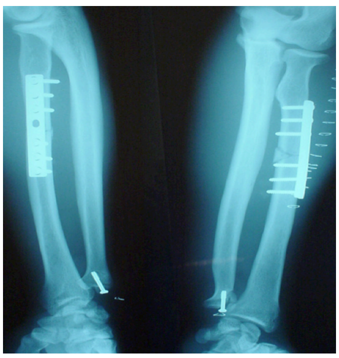
Intramedullary ulnar entry site is just **distal** to the olecranon apophysis (anconeus starting point), just anterior to the subcutaneous border of the proximal ulna on its lateral side.

If dual bone fixation is elected, then the **radius** is fixed first as it is usually more difficult. The **distal** radial entry site can be either through a physeal-sparing direct lateral approach through the floor of the first dorsal compartment or dorsally near the proximal extent of the Lister tubercle between the second and third dorsal compartments. Both of these entry points are approximately 1 cm proximal to the physis of the **distal radius**. Typically use small intramedullary nails (2.0 to 2.5 mm in diameter) to maintain some flexibility at the **fracture** site and stimulate appropriate callus formation.

The nails buried beneath the skin because complete **fracture** healing takes at least 2 months, often more. Because refracture can even occur with nails in place, protect children for at least the first month with a removable **fracture** brace.

Plating is preferred to intramedullary nailing when early malunion is present and callus formation is noted radiographically. Plating allows open osteoclasis and reduction. The plating technique is similar to that used in adults.





Anterior Approach for Radius [Henry's Approach]

Forearm supinated, begin longitudinal incision [lateral to biceps to radial styloid process]

Expose the biceps tendon by incising deep fascia on its lateral side;

Preserve LCN, which lies subcutaneously;

Protect the radial vessels; - fascia is incised between brachioradialis & FCR

Identify SRN

Proximal exposure: if more proximal exposure is required, then dissect between the brachioradialis and brachialis

Isolation of the Radial artery - the radial artery is best identified distally and followed proximally; superficial radial nerve are retracted radially revealing the proximal portion of the radial artery;

Radial artery lies beneath brachioradialis in middle part of forearm, and lies close to medial edge of wound; - because the radial artery is vulnerable during mobilization of brachioradialis, its branches to the brachioradialis must be ligated (bipolar cautery);

Brachioradialis is retracted laterally and the pronator teres is retracted medially; superficial branch of the radial nerve lies along under surface of the brachioradialis, which is protected by lateral retraction of the brachioradialis;

More distally, the dissection proceeds between the brachioradialis and the FCR

Dissection of the Forearm Muscles Off the Radius: -Supinator - proximally, and subperiosteally stripped from radius [PIN laterally]. Supinator insertion should be exposed in full supination & detached from radius.

Isolate & ligate leash of Henry; subperiosteally strip supinator from its insertion;

FDS insertion begins just distal to the bicipital tuberosity and is ulnar to the supinator;

-Pronator teres tendon is reflected subperiosteally in middle third of the forearm, insertion of muscle is preserved if possible

Dorsal approach of Thompson rarely done these days.

Plate used: 6 or 7 holed 3.5 LC DCP

Surface: Medial for ulna and anterior or lateral for radius; Prebent plate for lateral aspect of radius

Boyd's Approach for ulna

Position: - arm is placed on an upholstered arm board w/ medium elbow flexion and full arm pronation;

Surgical Approach:

- interneural approach: lies between ECU and FCU
- ECU muscle often extends past the posterior midline of the ulna and it must be divided to reach the bone;

- **Plate Position:** choose the surface on which it fits best; - posterior surface is good choice, since this is tension side;
- Fracture that has the least comminution (usually the ulna) is fixed first;
- if reduction is impossible the plate on the other bone is loosened and second bone reduced;
- after reduction and provisional fixation of both bones, pronation and supination are examined
- **comminution and segmental bone loss:** - comminution makes it difficult to restore bone to length; - in this situation interosseous membrane is identified and used for adequate rotation

Bone grafting: - it is generally recommended : when more than 50% comminution; - the indications for bone grafting have recently been challenged by Wright et al 1997, who were unable to find any advantages to bone grafting in a retrospective review of 198 both bone fractures; - if bone graft is used, it should be away from interosseous membrane to decrease risk of synostosis

IM locking nail

IM rod: Rush pin 16% NU
Sage Nail 7% NU

Currently: some surgeons Locked IM [failed plate; segmental; severe open fracture, osteoporotic]

Stainless steel Taper [SST] Biomet

Risk of PIN with interlocking nail

Elastic nail is commonly used for pediatric fracture [Nancy Nail]

Presently: Unusual segmental #
Very osteoporotic bone
? Highly selectively professional sportsman

COMPLICATIONS

1. Redisplacement/Malalignment

Occurs in 10%

Screen radiography at 1 and 2 weeks after reduction.

The most common explanations for loss of **fracture** reduction are cast related (poor casting technique, no evidence of three-point molding).

2. Forearm Stiffness

Significant forearm stiffness, with pronation loss occurring almost twice as frequently as supination loss.

Stiffness that exceeds that expected from bony malalignment alone and stiffness that occurs with normal radiographs are indications of fibrosis of the interosseous membrane.

3. Refracture [Schwarz JBJS 78 B: 740]

Refracture occurs more often after forearm shaft fractures in children than after any other **fracture**. It occurred at an average of 6 months after original injury and was more common in males (3:1) and in older children (approximately 12 years old).

Refracture rates of 4%[98] to 8% have been reported in pediatric diaphyseal forearm fractures.

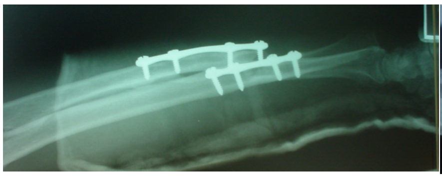
Bannister reported that diaphyseal forearm fractures were eight times more likely to refracture than metaphyseal fractures.

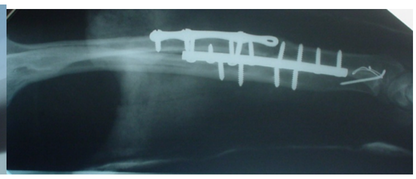
Suggested that internal fixation is necessary after refracture.

Refracture after plate removal has been discussed frequently in the literature and appears to be associated with decreased bone density beneath the plate.

<u>Type of plate</u>

21%	with 4.5 DCP
6%	DCP (3.5%),
7%	Semitubular plate
0%	PC plate[**J Orthop Trauma, 10,87-92,1996]**





4. Malunion

More deformity in the predominant plane of motion is acceptable in fractures near physes of long bones than in diaphyseal fractures. Normal motion can be preserved despite persistent radiographic abnormality.

Early malunions (up to 4 or 5 weeks after injury) can be treated with closed osteoclasis under anesthesia. A Kirschner wire is used to make multiple holes in the region of the malunion before forcefully manipulating the bone back into alignment. Internal fixation may be needed.

Once significant callus is present, a corrective osteotomy and internal fixation with flexible intramedullary nails can be difficult or impossible because the **fracture** site is now blocked with callus. This may require formal open procedure, osteotomy and plate fixation.

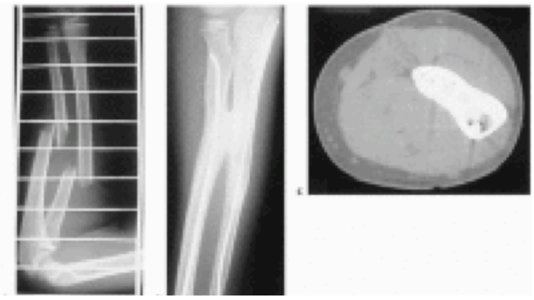
Many fractures that heal with angulation or rotation of more than the established criteria regain full motion and have an excellent cosmetic outcome. Fractures may require corrective osteotomy if they fail to remodel after an adequate period of observation or if adequate motion fails to return.

5. Delayed Union/Nonunion

Normal healing of closed pediatric forearm shaft fractures occurs at an average of 5.5 weeks (range 2 to 8 weeks). Delayed union can be practically defined as a failure to demonstrate complete healing (four cortices) on sequential radiographs by 12 weeks after injury, which exceeds the upper limit of normal healing by about 1 month. Nonunion can be defined as absence of complete bony union by 6 months after injury.

These rare after closed forearm shaft fractures in children 0.5% rate.
Plated pediatric forearm fractures indicated a 3% nonunion rate 24% (21/89) of these were open fractures. In the absence of such extraneous factors, nonunion of pediatric forearm fractures seems to be related to surgical treatment.

6. Cross-Union/Synostosis
Results in complete loss of forearm rotation.
Most cross-unions that form after pediatric forearm shaft fractures are type II lesions
Although some series of adult forearm fractures reported synostosis rates of 6% to 9%,
In children, it usually is associated with high-energy injuries, radial neck fractures, and surgically treated forearm fractures.



Postoperative synostosis after forearm fractures in children is almost exclusively associated with plate fixation. The risk of cross-union is increased when open reduction and internal fixation of both-bone fractures are done through one incision.

Interposition of inert material (such as Gore-tex) has been used to decrease the chances of recurrent synostosis.
An alternative treatment is corrective osteotomy if the patient is synostosed in a position of either extreme pronation or supination.

7. **Infection:** Grade I injuries. An overall 1.2% rate of deep infection and a 0.6% rate of superficial infection after current open **fracture** treatment protocols.

8. Neurapraxia
The median nerve is the most commonly injured nerve with forearm shaft fractures. Usually it is simple neurapraxia. Constricting **fracture** callus and fibrous tissue also have been known to cause nerve palsies. If signs of progressive nerve recovery (e.g., advancing Tinel's sign, return of function) are not present by the **end** of the third month after injury, further diagnostic work-up.

Nerve injury after internal fixation is always a concern. Luhmann reported an iatrogenic nerve injury rate after fixation with intramedullary Kirschner wires or Rush rods. Both were ulnar nerve injuries that resolved in 2 to 3 weeks.

Certain sensory nerves also are at risk for iatrogenic damage during surgical forearm **fracture** treatment, especially the superficial branch of the radial nerve. The branching pattern of SRN nerve is complex, and efforts must be taken to protect it during insertion of intramedullary nails through **distal** radial entry points.

9. **Compartment syndrome**

10. Tendon Rupture

The pronator quadratus also is vulnerable to **fracture** site entrapment in the **distal** third of the **radius** and ulna, and it can block reduction of **distal**-third forearm fractures. FDP and FDS entrapment within ulna or radius can occur. Excellent restoration of finger motion can be achieved, even when the release is done up to 2 years after the **fracture**

11. **Plate removal**: Langkamer: 40% complications on removal of forearm plates [JBJS 72A: 601]

Fracture Risk/Fracture Prevention

The rate of forearm fractures has increased

Preventing these injuries remains an admirable but elusive goal.

Two main avenues of research have been explored: optimizing safety during activities known to be associated with forearm fractures, and investigating biologic mechanisms related to **fracture** risk.

1. The relationship between in-line skating
   1 in 8 children sustaining a **fracture** on his or her first skating attempt.
   Prevention efforts have focused largely on protective gear.
   Wrist guards have been shown to decrease **distal** forearm bone strain
2. Trampolines are another target of injury prevention
   Safety recommendations have ranged from constant adult supervision and one-child-at-a-time use to outright bans on public trampoline use.
3. Children who avoid drinking milk have been shown to increase **fracture** risk
4. Too little physical activity (as measured by television, computer, and video viewing) has been associated with increased **fracture** risk
5. Childhood obesity is a growing problem also has been found in females who **fracture** their forearms.