Journal of Surgery
Burnei G. J Surg 6: 1453
www.doi.org/10.29011/2575-9760.001453
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Review Article

# Scaphoid Fractures in Children: Particulararities and Difficulties of Diagnosis and Treatment

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**Citation:** Burnei G (2021) Scaphoid Fractures in Children: Particulararities and Difficulties of Diagnosis and Treatment. J Surg 6: 1453. DOI: 10.29011/2575-9760.001453

**Received Date:** 06 December 2021; **Accepted Date:** 10 December 2021; **Published Date:** 14 December 2021

## Abstract

Scaphoid fractures in children are rare and diagnostic errors have an increased rate due to difficulties in radiological interpretation of fractures of a partially cartilaginous bone.

Data reported and published in the pediatric literature showed that 21% to 97% of images provided by simple X- rays cannot be considered revealing to exclude a fracture.

For medical practice is ok to be known that the serial, frontal, oblique and „scaphoid" X-rays incidences reduces the risk of diagnostic errors, although in these situations errors may occur - estimated from 5% to 20%. The final diagnostic is established by magnetic resonance imaging (MRI).

Fractures type 1 and 2 after D'Arienzo, may cause growth and developmental disorders, therefore, the orthopedic treatment is preferable and after 6 months to resort to surgical intervention, only, if there is an express indication.

The treatment of choice is the orthopedic one and the surgery is performed on fractures with displacement, in older children and adolescents or in case of major complications, such as pseudarthrosis or necrosis of the proximal pole.

**Keywords:** Scaphoid Fracture; Imaging Examination Certifies the Diagnostic; The Principles of Orthopedic Treatment; Surgical Indications; Treatment of Complications

## Introduction

By the age of 6, the scaphoid has a cartilaginous structure. Fractures usually occur after this age and their incidence increases with age, especially between 12-15 years. However, the incidence of scaphoid fractures in children under the age of 15 is very low.

Cristodoulou and Colton [1], reported that the scaphoid fractures frequency in children is 4 per thousand of total fractures and 4.5 per thousand of total thoracic limb fractures. The incidence of these fractures is 3% of the total fractures of the hand and radiocarpal joint. However, carpal scaphoid fractures are the most common, accounting for 80-90% of carpal fractures [2].

Exceptions are also reported in the literature.

The diagnosis of scaphoid fracture can be difficult when it has a chondral or osteochondral structure. Scaphoid fractures in children under the age of 6 occur, as a result of road accidents and are sometimes diagnosed after several years, even after 6-7 years.

Larson [3], has diagnosed a scaphoid fracture in a 5-year-old and 9-month-old child, who suffered a crushing injury. Pesamosca [4], presented 2 children who had a scaphoid fracture (2/4), after road accidents at the age of 4 years and 2 months, respectively 5 years and 7 months. The diagnostic was established after approximately 3 and 6 years, respectively. As a result of serious injuries, the patients underwent several surgeries for other visceral

and osteoarticular injuries. Late scaphoid detected fractures were healed, but the children showed pain and radiological signs of arthrosis of the radial carpal ray.

Although it seems a minor problem, many doctors have dealt with this field. Matti-Russe had reference concerns, which shed light on the treatment.

Along with them, significant contributions were made by Vahvanen, D'Arienzo, Slutsky, Kang and others. In Romania, there were a number of renowned doctors, heads of clinics and academics in the field of Pediatric Surgery, who practiced pediatric orthopedics, such as: Moroz, Gotia, Mironescu, Tepeneu, Tica and Moldovan.

At a specialized congress, Moroz was a follower of a conservative therapeutic concept, by immobilization in a plaster cast, supported and well managed. The method was also supported by Socolescu and later by all participants. Thus, a consensus was established regarding the orthopedic treatment in scaphoid fracture. This method, also practiced in centers from many countries is exposed to orthopedic treatment.

In Orthopedics and Traumatology, N Gorun, C Baciu, C Radu and others took care of the scaphoid fractures. I. Dobre has described in 1981 the osteoplasty of scaphoid pseudarthrosis with muscular pediculate graft taken from the ventral face of the radial epiphysis [5].

**Particularities**

Carpal bone fractures are rare in children. Scaphoid fractures are the most common fractures of the carpus and have the highest incidence in children aged 12 to 15 years.

The low number of scaphoid fractures in children is due to its configuration and structure, which at the periphery is covered by cartilage.

The cartilage provides protection for the ossification center, so that, a considerable force is required to produce a contusion or fracture. Because of this and due to the evolutionary changes of the center of ossification, in relation to age, the type of these fractures differs from that of the adult. During the final ossification period, avulsion fractures occur accompanied by lesions of the soft tisuues; this thing may be explained by the fact that, the most common fractures at this age, occur at the distal pole. The program of ossification in the distal and proximal direction makes the pattern of fractures in adolescents to be similar to that of adults.

The most common traumatic mechanism of fracture is accidental fall on the hand, with the forearm in pronation and the hand in a forced extension.

There are no considerable differences from the adult in terms of the mechanism of trauma, other than the rarity of cases and the increased rate of diagnostic errors, due to the difficulties of radiological interpretation of fractures of a partially cartilaginous bone.

For medical practice, it is good to know, the development, the mechanism of action of the trauma, the associated traumas, the diagnostic and the treatment, as an optional method.

**Scaphoidt Development**

The scaphoid is initially composed of cartilage, which is covered by epiphyseal cartilage and, progressively, an enchondral ossification takes place. The intrauterine cartilaginous pattern extends and develops in the postnatal period. The ossification nuclei appear at 5 years and 4 months in boys and 4 years and 6 months in girls.

Occasionally multiple ossification centers may appear, but they unify rapidly by coalescence. Cases of bilateral congenital bipartite scaphoid are reported followed by early ossification of the scaphoid [6]. This rare abnormality must be diagnosed by magnetic resonance imaging, to differentiate it from traumatic scaphoid pseudoarthrosis.

The first cases were communicated by Gruber and Pfitzner [7]. Gruber [8], has described 4 types of cases after 3007 disections and Pfitzner [9], 9 after 1450 anatomical studies. There is an encondral ossification that extends eccentrically to total ossification, at 15 years in boys and 13 years and 6 months in girls.

The cartilaginous pattern of the scaphoid is completely ossified when the skeleton is mature and when the bone structure of the scaphoid is covered by the covering cartilage. The process of chondrous transformations, development and aging process depends on the degree of blood infusion provided by the vessels occupying the central canal of the cartilaginous scaphoid.

**Vascularization**

The scaphoid is vascularized by two scaphoid branches, dorsal and volar, which, in turn, arise from two other branches, the dorsal branch and the volar branch of the radial artery [10]. These two branches of the radial artery give, each of them, a main scaphoid branch, one dorsal and one volar and several secondary ones which enter the scaphoid through several vascular orifices/ ports.

At the entrance, the main scaphoid dorsal branch is divided into several longitudinal intra-bone branches, which ensures vascularization in the proximal and middle area; 70-80% of the volume of the scaphoid bone mass. The other scaphoid branch, the volar branch, vascularizes the distal area of the scaphoid.

**The Pathogenic Mechanism**

The scaphoid is integrated, not only structurally but also functionally, in the meso-acromielic radial segment.

This segment represents the main pillar that receives, first of all, the impact of the shock on the pronated and forced hand in dorsal flexion. The support is made on the thenar eminence and the scaphoid is the first bone to take over this impact (Figure 1). This is the reason why the scaphoid fractures are the most common fractures of the carpal bones.

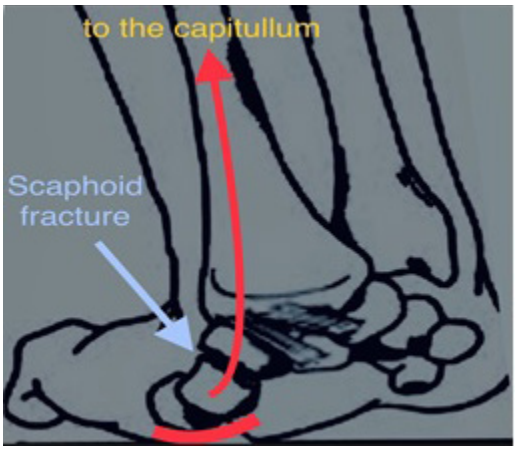


**Figure 1**: The meso-acromielic segment that takes over the impact force when falling on the hand with support in the tenar area has the vertical axis scaphoid-radius-capitullum.

The usual mechanism is: falling on the outstretched hand with the radiocarpal joint forced, in hyperextension. The intensity of the traumatic agent is variable and, as such, the shock of falls on the hand causes, not only the scaphoid fracture, but also other associated lesions: fracture of the distal extremity of the radius, distal radioulnar diastasis, carpal dislocations, etc.

When the recurrent force of the fall on the hand is lower, the diagnostic comes down to: compaction of the distal epiphysis of the radius, capsular ligament extensions, enthesitis and contusions.

**Classification**

The aging process period of the scaphoid from the cartilaginous structure to the bone structure lasts, on average, from 6 years to 15 years. During this period, the patient's age, the degree of bone aging process and the location of the fracture are significant factors that mutualy interact?

These factors determine the type of fracture and the treatment.

**D'Arienzo Classification** [11], takes into account the patient's age and degree of ossification. This classification divides scaphoid fractures into three types.

**Type 1** includes fractures that occur in children under 8 years of age. This type of fracture affects the chondral structure of the scaphoid and the fracture line passes through the growth nucleus. These are rare fractures and only MRI scanning is concludent for a diagnostic.

**Type 2** includes osteochondral fractures and occurs in children aged 8 to 12 years.

Types 1 and 2 can give growth and development disorders, that is why the orthopedic treatment is preferable and, only after 6 months the surgical treatment should be considered: only if there is an express indication.

**Type 3** fractures are more common compared to type 1 and 2, and occur in adolescents over 12 years. In adolescents, the scaphoid is ossified to a considerable extent and these fractures are similar to those in adults.

The difference consists in the fact that the fractures in the adolescent are cured in a higher percentage by conservative treatment.

**Anatomical classification** takes into account the location of the fracture. It holds attention because it includes all types of fractures. The distribution of scaphoid fractures in children by type and location is unknown. Isolated cases with different locations are mentioned, except for the fracture of the tuberosity.

**Distal pole fractures** are the most common and comprise transverse fractures and the avulsion of the distal pole.

The large number of transverse and avulsion fractures located in the distal third of the scaphoid is very typical in children.

The fractures of the middle area are frequently oblique and are prone to pseudarthrosis.

Proximal pole fractures are extremely rare in children. Fabre and Cristodoulou [1,12], reported one, respectively two of the proximal pole, and Duteille and Greene [13,14], two, respectively one case of proximal pole pseudarthrosis. Proximal pole fractures have an increased risk of non-union. Although there is this risk, the possibility of curing them by conservative treatment for a period of time of 18 months must also be considered [15].

**Russe classification** [16] divides the scaphoid fractures by location and type of fracture (Figure 2). The following types of fractures are differentiating in adults, by location: fractures of the proximal area (20%), fractures in the middle area (70%) and fractures of the distal area (10%).

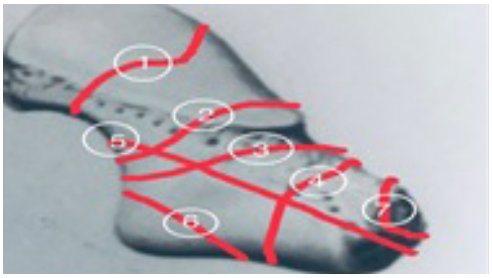


**Figure 2**: Russe classification, by location and type of fracture:

1. upper pole fracture 2. transverse fracture with intraarticular trajectory 3. oblique fracture 4. lower pole fracture. 5. vertical fracture. 6. tuberosity fracture 7. avulsion fracture.

Depending on the longitudinal axis of the scaphoid, it divides the fractures into the following types: fractures with horizontal trajectory (35%), fractures with oblique trajectory (60%) and fractures with vertical trajectory (5%).

This classification is also useful in adolescents when the fracture has a surgical indication to ensure good interfragmentary compression and a good stability.

**Imaging (Scan)**

**Simple X-Ray**. To get a more edifying image for the existence of a scaphoid fracture, a simple X-ray is done in four projections: anteroposterior, lateral, oblique and in the so-called position „for scaphoid", with the hand in pronation, dorsiflexion and ulnar deviation, a special position that allows a better visualization of avulsion fractures.

These serial incidences reduce the risk of diagnostic errors, although in these situations errors estimated from 5% to 20% may occur.

These X-ray may show: a fracture with or without displacement, changes in the soft tissues a scapho- semilunate dislocation that may accompany the fracture in adolescent.

The presence of a fracture requires the following specifications:

• Location: proximal pole, middle area, tuberosity or distal pole.

• Involvement of joint surfaces

• Displacement

• The presence of a possible angulation between the proximal and distal fragment.

A rigorous radiological evaluation also assesses the following data: carpal alignment, scapho-semilunate bone space, dislocation of the semi lunate bone, other fractures association; the Pouteau Coles fracture or other fractures of the carpal bones and the presence of a vascular necrosis if the fracture is older.

In case the fracture is not visualized and only 2 or 3 incidents have been made and when the "scaphoid" radiograph is missing, especially, it is recommended to perform it or repeat them, if the clinical signs become more obvious, at 7-10 days. The data reported and published in the pediatric literature show that in proportion of 21% up to 91% of the images provided by simple X-rays cannot be considered revealing to rule out a fracture.

In a proportion of 13%, the fractures cannot appear radiologically until 1-2 weeks after the trauma.

Currently, the simple X-ray is used to assess the progressive healing.

Radiography can also be used in case of discrepancy between bone age and chronological age to make therapeutic decisions. If the radiographs are inconclusive, other investigations are used.

**Ultrasound and bone scintigraphy** are useful in children with fractures on a scaphoid with chondral and osteochondral structure.

**Computed tomography (CT)** can be used in older age groups: between 8 and 11 years and in children over 12 years. Images are relevant in 90-98% of cases. Also, it can also be used to assess fracture union. CT reading establishes the angulation at the level of displacement and CT-3D orients/guides us on the size of the displacement.

CT and magnetic resonance imaging scans can help assessing the carpal collapse, scaphoid collapse, lack of scaphoid union, bone loss and the detection of osteonecrosis [17].

**MRI** shows us especially the chondral and osteochondral fractures, where radiological images are not reliable. Scaphoid fractures may remain undiagnosed at the initial radiographic examination and we may be surprised to see that in a late stage we find the presence of fracture, based on radiographic signs, given by the bone regeneration reaction [18].

The late diagnostic of fracture, 5 weeks after onset, when the child has residual pain, swelling and sensitivity to palpation in the anatomical tab reduces the effectiveness of conservative treatment. Therefore, MRI can be used in the initial assessment of scaphoid fractures in children.

The final diagnostic is established by MRI: fractures appear in 25% of cases with negative radiographs, in 9% of cases carpal injuries occur, and in 4% of cases other traumatic injuries occur.

If the X-Ray is equivocal in 10 cases, MRI shows 4 fractures. All radiologically diagnosed fractures are also evident on MRI images. For the diagnosis of scaphoid fractures that occur in children under the age of 8, MRI is the best option for a safe evaluation. MRI

builds us especially in the case of chondral and osteochondral fractures where radiological images are not reliable (Figure 3).

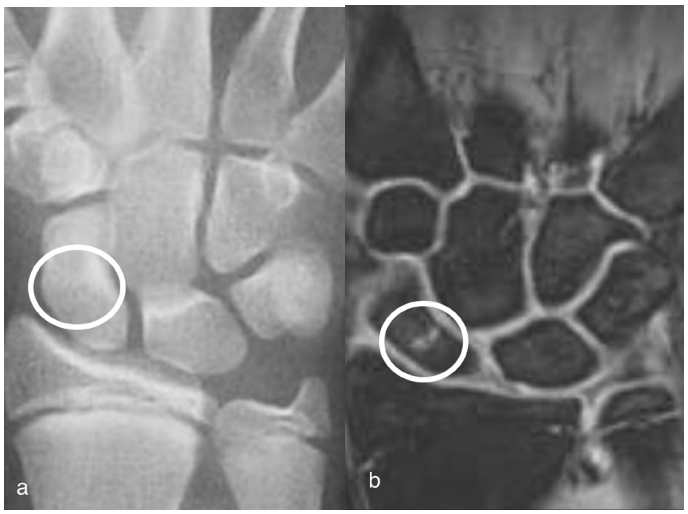


**Figure 3:** D'Arienzo type 2 osteochondral scaphoid fracture: a) the radiological image highlights the contour of the middle area discreetly prominent and raises the suspicion of an hidden fracture. b) MRI scan confirms the suspicion and shows an incomplete fracture well highlighted by the contrast agent.

Modifications of the soft tissues may suggest the presence of a recent scaphoid fracture and consist of presence of an intra-articular fluid in the capsule recess, swelling on the dorsal face of the radiocarpal joint and the sign of the fat layer detected by the presence of a convex line on the convex slope of the scaphoid. Soft tissue changes cannot confirm or refute/invalidate a scaphoid fracture, unless it is present on scan.

Scapho-semilunate bone dislocation may be associated with a scaphoid fracture due to rupture of the scapho-semilunate bone ligament. This dislocation is highlighted by the sign of Terry Thomas, the widening of the scapho- semilunate joint space [19].

## Treatment

**Orthopedic treatment** is indicated for most scaphoid fractures [20] except for displaced fractures in older children and adolescents. Immobilization in a plaster cast should be done promptly, festively and appropriately, immediately after trauma in all patients, who have an edifying history and relevant clinical data, regardless of the radiological result, until the establishment of the final diagnostic by MRI evaluation.

If the diagnosis is denied, the cast imobilisation is maintained for 2 to 4 weeks. Fracture identification is followed by immobilization in a short ante-brahi-palmar/ wrist plaster cast, if the lesion is an avulsion fracture or an incomplete fracture.

Immobilization in an ante-brahi-palmar/wrist plaster cast with long brachial segment continues if the fractures are complete. The complete immobilization of the thumb is used for active children. Immobilization of patients, who have been diagnosed late, for various reasons, can sometimes lead to progressive union, especially in children under 10 years of age. If the progression of union is noticed, after 4-6 weeks, the long plaster cast can be replaced with an ante-brahi-palmar/wrist plaster cast with short segments on the forearm and thumb or with orthosis.

Fractures in the middle area, in adolescents, require special attention because in some cases, these fractures have a surgical indication and some of the scaphoid pseudarthrosis come from these types of fractures. Their immobilization is done in long plaster casts to be effective. They are maintained until healing, which must be confirmed radiologically or by MRI. The healing time is on average 6-7 weeks but varies from 3 to 16 weeks and depends on the location of the fracture.

Unhealed fractures after 6 months are considered pseudoarthrosis and are treated as such. Few cases of acute fractures are reported; only those in the middle area. Also the number of cases that failed after orthopedic treatment is very low; 1 case in 64 patients. In adolescents, the rate of lack of union, after plaster immobilization is 3.4%, 1 of 29 [21].

More than 170 cases of scaphoid pseudarthrosis have been reported in the literature; only 4 at the distal pole and 2 at the proximal pole. Pseudarthrosis is the consequence of late presentation of patients to the doctor or a misdiagnosis [22].

### Surgical treatment

**Open approach** has the following indications [17].

- Fractures with a displacement of 1 mm or more than 1 mm.
- Comminuted fractures (micro-fractures)
- Some proximal pole fractures
- Fractures diagnosed and treated late
- Sagittal angular fractures with an angle greater than 45 degrees
- Patients with reduced compliance, evaluated anamnestically

**Arthroscopic treatment** is done for both, fractures and pseudarthrosis [23] [24]. The advantages of arthroscopy are also found in vascular grafts [25].

## Complications

### Pseudartrosis

In children, even in cases of properly treated scaphoid fractures, the scaphoid pseudarthrosis may occur [26]. The incidence of this complication is considered rare. Faber [12], reported 8 cases of scaphoid pseudarthrosis after promptly treated fractures with adequate immobilization. Much more common are cases that occur after diagnostic errors due to reduced clinical signs, lack of clear radiological signs or difficulties in interpreting images on an interpretation of images on an immature skeleton.

Scaphoid pseudarthrosis can occur in the following situations:

- Uncertain anamnestic data and inadequate X-rays.

- Clear anamnestic data, common symptoms present, erroneous or neglected diagnostic and inadequate treatment.

- Anamnestic data where multiple falls are recorded during the game with other children or the practice of a sport followed by the appearance of a chronic discomfort or pain.

### Orthopedic treatment

The ability of bone regeneration in children makes the healing of scaphoid fracture almost certain and scaphoid pseudarthrosis to be encountered quite rarely. Scaphoid pseudarthrosis occurs almost exclusively in children aged 9 to 15 years. Larson [3] exposes a case of scaphoid pseudarthrosis at the age of 5 years and 9 months. Cures with good functional results may occur in the case of scaphoid pseudarthrosis that may have required surgical intervention. Pesamosca [4] treated 2 cases of pseudarthrosis (2/4) in 2 polytraumatized children, aged 10 years and 12.4 years, by immobilization in plaster cast and orthoses for 20 weeks.

Healing was confirmed radiologically and the functional results were very good. Extending the period of immobilization may be intolerable for some children or parents, and then resort to surgical treatment after discussions that consider the risks and benefits, is the last solution.

Sometimes the lack of insurance of patients or their parents can be a risk factor in the occurrence of nonunion or pseudarthrosis by increasing the time elapsed from the time of fracture and the time the conservative treatment or intervention was started [27].

### Surgical Treatment

Several methods have been described for surgical treatment. Regardless of the method used, very good results were obtained after the surgical treatment [28] [29]; the healing rate was 100% even if re-interventions were needed. The degree of mobility was good and the pain disappeared. Intermittent discomfort may persist during intense activities.

The surgical methods used in the treatment of scaphoid pseudarthrosis in children are:

- Autogenic bone-graft substitute by anterior approach.

- Bone graft by anterior approach with fixation.

- Iliac bone graft and fixation.

- Vascularized bone graft is recommended for the treatment of scaphoid non-unions with osteonecrosis [17].

Internal fixation is differentiated, according to the age and type of fracture. The following can be used: AO sponge screw, Matti-Russe procedure [30] [31], with or without graft and Herbert screw fixation, Herbert or headless screw fixation, open reduction and screw fixation, or closed reduction and percutaneous fixation with screw. Percutaneous fixation of acute displaced scaphoid fractures has union rates comparable to those treated by plaster immobilizations, but with a faster return to activity and without any significant difference in the complication rate [32].

If, following the surgery, one of these techniques was used for scaphoid pseudarthrosis and no cure was obtained, the patient may be subjected to a new surgery using the same method or another method of fixation and the autogenic bone graft, preferably the vascularized graft. The post-surgery immobilization period is variable and can be shortened if the fixation is as good as possible. In principle, the period of post-surgery immobilization is 4 weeks to 3 months and depends on the method of treatment used.

### Osteonecrosis of the proximal pole.

Non-union and ischemic necrosis of the proximal pole fragment, complications more frequently observed in adults [33] may also occur in children [3]. This complication is possible and is extremely rarely reported (Figure 4). Waters and Stewart [34] report this complication in 3 adolescents with a mean age of 14.5 years. These patients were treated with vascularized bone graft from the distal end of the radius after the Matti-Russe procedure. After 5 years, the patients had no longer pain and had no restrictions on their activities, although dorsiflexion of the hand and ulnar deviation were limited. Radiography showed the union of pseudarthrosis.


**Figure 4:** Proximal pole necrosis after an orthopedically treated cranial pole fracture. The widened scapho-semilunate space indicates the Terry Thomson sign is present.

**Growth and development disorders.**

The lesions initially appear in the scaphoid nucleus, as a result of the use of Herbert or "headless" screws, so it is recommended to use these screws in children over 11 years old. In extreme cases, Kirschner wire fixation can also be used on children.

**Migration of osteosynthesis material**. Screws migrate when growth and development disorders occur in the scaphoid nucleus. K wires migrate more frequently and their ablation is used.

## Conclusions

The diagnosis of scaphoid fractures in children is established by imaging. The MRI is the scan of choice and avoids diagnostic errors.

The most effective and accepted treatment by pediatric orthopedists is conservative and consists in immobilization in a cast. A prompt and an appropriate treatment leads to the healing of patients.

In older children and adolescents, surgical treatment is indicated for displaced fractures or lack of union after 6 months from onset.

The appearance of complications is possible even after a correct orthopedic treatment and is treated surgically.

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