# Dating of Long Bone Fracture Healing among Egyptian Pediatrics by Radiography (X-Ray)

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## Abstract

**Background:** Estimating the timing of skeletal injury accurately is of great importance in forensic cases and has a significant bearing on the judicial process (related to abused children). This work aimed to assess dating of long bone healing in fractures occurring to children aged from 1 to 18 years through using plain radiography (X-Ray) which can determine 6 features of fracture healing process that are especially important in alleged cases of child abuse. The most commonly affected ages were "1-6" years presenting 68%. Males were the majority of cases (56%). The illustrated data of each feature of healing (6 features of fracture healing) form a prototype timetable of fracture healing. These data suggest that fractures with soft-tissue swelling alone are **acute fracture** (< 1 week old). Fractures with periosteal reaction alone are likely to be **recent fracture** (between 8 days and 3 weeks old). Once Remodelling, bridging & hard callus fractures detected then **old fracture** is expected (more than 6 weeks old).

***Key words:*** *dating, long bone, fracture healing, X- ray.*

## Background

One of the biggest challenging areas of pediatric medicine is what relating to child abuse. Child abuse includes wide variations of injuries and assaults which includes social, emotional and sexual in addition to physical matters. Therefore, the diagnosis of a child as being suffer from an event of abuse has important social, civil and criminal implications[1] .Child mortality and morbidity are a significantly outcome from exposure of those children to maltreatment and abuse[2].

To investigate children who have suffered potential abuse, the investigation must be multi-disciplinary and involve healthcare and social professionals, physicians with appropriate medical subspecialties and paediatricians. Radiology supplies a relatively small but important role to the investigation of visceral and skeletal injuries[3].

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## Methodology

The study represents collaborative research between Forensic Medicine and Clinical Toxicology Department and Diagnostic & Interventional Radiology Department, Faculty of Medicine, Cairo University, Egypt.

### Study design and setting

This study is a prospective, cross-sectional study that was conducted on injured paediatrics, of known injury timing in the period between January 2017 to January 2018.

### Study population

For this study one hundred patients of both sex aged 1- 18 years were selected during the study period and subdivided into 3 main groups, group 1: 68 children (1 to 6 years), group 2: 22 young (< 6 to > 12 years) and group 3: 10 young from (< 12 to 18 years). Potential participants who had Unknown time of fracture, Fractures need to be treated with internal fixation, Patients with co-existent

head injury and who had metaphysial fracture were excluded from the study.

The study was conducted according to the declaration of Helsinki and the protocol was approved by Ethics Research Board of both departments[4] . All participants provided written informed consents by their legal guardians before being enrolled in the study.

## Methodology in Detail

Cases were analysed according to Demographic data of the patients: age, sex, time of imaging (measured in days since injury), date 1, 2, 3, 4, 5, 6 and 7 up to 50 days or more from time of fracture.

## Radiography

Radiographs were presented to the pediatric radiologist in a random order where the identity, age of the child, time and cause of injury were unknown for him. They were supplied in batches of 6–12 to minimize memory bias and fatigue and he assessed each radiograph with irregular time interval.

**Interpretation of radiographs:**

The presence or absence of each of the following six radiographic features of fracture healing was scored for all radiographs.

***1- soft-tissue swelling***, which was defined as disruption of the soft-tissue planes or the presence of an effusion in a supracondylar fracture.

***2- periosteal reaction,*** which was defined as linear elevation and calcification of the periosteum along the shaft of the bone around or adjacent to the fracture site.

***3- soft callus,*** which was defined as the fluffy appearance of early new bone around the fracture site which gradually ossifies and calcifies.

***4- hard callus,*** which was defied as well-demarcated new bone with a dense edge that is nearly as dense as the cortex as more mature callus develops.

***5- bridging,*** which was defied as the loss of fracture line definition with complete bridging of the fracture gap by a soft or hard callus.

***6- remodeling,*** which was defied as the complete healing with the shape at the fracture site returning to that of the original bone[7].

Radiologist of the study scored films with an initial 5-point scale plus an additional score, P, for undetermined.

Radiographs time was grouped into bands based on the known age of the fracture. The time bands were selected according to the data (with at least 20 radiographs in each time frame) and to reflect the age estimation process in practice. Narrow time bands were possible for the first week, with increasing width thereafter. The time bands were: 1–2, 3–7, 8–14, 15–21, 22–35, and 36 days up to 50 days. They were classified as follows:

Date 1: 1-2 days / Date 2: 3-7 days / Date 3: 8-14 days / Date 4: 15-21 days / Date 5: 22-35 days / Date 6: 36-50 days / Date 7: < 50 days.

## Statistical Analysis

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 25. Data were summarized using frequency (count) and relative frequency (percentage) for categorical data. For comparing categorical data, Chi square ($\chi 2$) test was performed. Exact test was used instead when the expected frequency is less than 5[8] P-values less than 0.05 were considered as statistically significant.

## Findings

302 radiographs were done as follows: (97 cases had radiographs at date 1), (48 cases had radiographs at date 2), (52 cases had radiographs at date 3), (44 cases had radiographs at date 4), (43 cases had radiographs at date 5), (14 cases had radiographs at date 6), (4 cases had radiographs at date 7).

Results show that 68 % of cases were from 1-< 6 years old, 22 % of cases from 6 - <12 years and 10% of cases 12- 18 years old, according to sex; 56% of cases were males & 44% of cases were females.

Figure(5) shows *tissue swelling* only detected during date 1 by 33.8% of cases *Periosteal reaction* started to be detected during date 1 by 10.8% of cases, it was detected during date 2 in 3.4% of cases, during date 3 in 69.4% of cases, in 81.2% of cases during date 4, in 88.5% of cases during date 5. During date 6; it was detected by 50% and in 100% of cases during date 7. *Soft callus* detected only during date 6 in 25 % of cases. *Hard callus* started to be detected during date 1 by 10.8% of cases, it was

detected during date 2 in 10.3% of cases, during date 3 in 58.3% of cases, in 75% of cases during date 4, in 80.8% of cases during date 5. During date 6; it was detected by 50% and in 100% of cases during date 7. *Bridging* started to be detected during date 1 by 3.1% of cases, it was not detected during date 2, during date 3 in 27.8% of cases, in 21.9% of cases during date 4, in 57.7% of cases during date 5. During date 6; it was detected by 50% and in 100% of cases during date 7. *Bone remodelling* started to be detected during date 4 by 3.1% of cases, it was detected during date 5 in 19.2% of cases & lastly detected in 50% of cases during date 6.

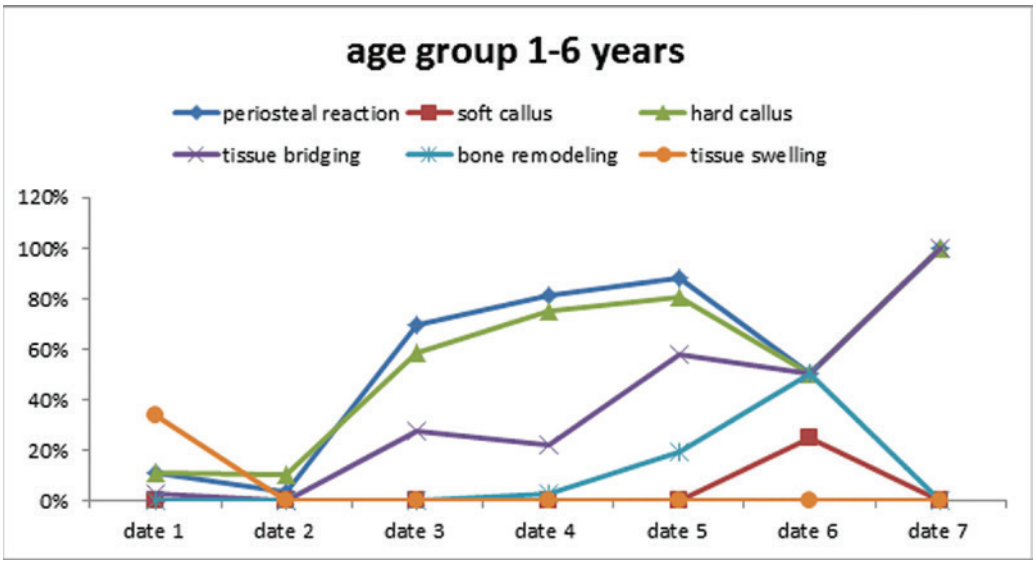


**Figure (5): Collective graph for 6 signs of healing during the seven dates for age group (1-6 years).**

Figure (6) shows *tissue swelling* started to be detected during date 1 by 19% of cases, it was detected during date 4 in 20% of cases and lastly detected during date 5 in 36.4% of cases. *Periosteal reaction* started to be detected during date 1 by 9.5% of cases, it was detected during date 2 in 38.5% of cases, during date 3 in 20% of cases, in 60% of cases during date 4, in 72.7% of cases during date 5. During date 6; it was detected by 75% and in 100% of cases during date 7. *Soft callus* was only detected during date 5 by 18.2%. *Hard callus* started to be detected during date 1 by 19% of cases, it was detected during date 2 in 61.5% of cases, during date 3 in 30% of cases, in 40% of cases during date 4, in 81.8% of cases during date 5. During date 6; it was detected by 75% and in 100% of cases during date 7. *Bridging* started to be detected during date 1 by 9.5% of cases, it was detected during date 2 in 15.4% of cases, during date 3 in 10% of cases, in 81.8% of cases during date 5, during date 6; it was detected by 75% and in 100% of cases during date 7. *Bone remodelling* started to be detected during date 2 by 15.4% of cases & lastly detected during date 7 in 100% of cases.

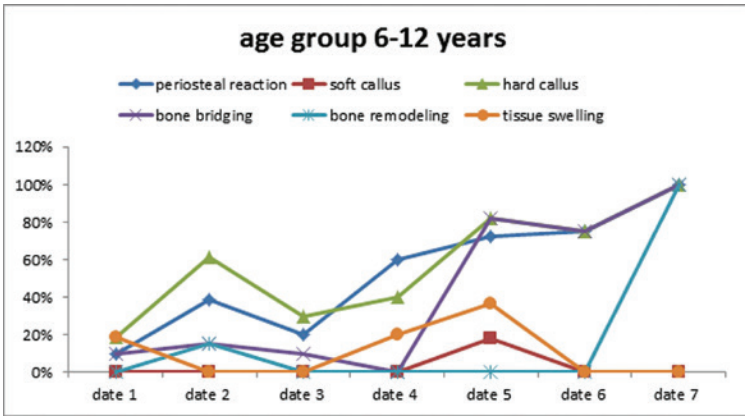


**Figure (6): Collective graph for 6 signs of healing during the seven dates for age group (6-12 years).**

## Discussion

In forensic cases, it is highly important to estimate the timing of skeletal injury appropriately as it has a significant bearing on the judicial process[9].

The study showed that the most commonly affected ages "1-6" years followed by< 6-> 12 years and the least ages affected were <12– 18 years. These results are in agreement with the results obtained by Prosser[7,9] who showed that broken bones are very common in childhood who have more physically active lifestyles and their fractures are generally less complicated than fractures in adults. As age increase, bones become more brittle and more likely to suffer fractures from falls that would not occur in young age. This in contrary to study done by Islam[5] who showed that most of cases were adolescence (8-17) years.

In this study, males represented the majority of cases (56%) in comparison to females (44%), these results are coincident with the results obtained by Islam[5], where boys 67% of cases. The other studies did not mention gender as point of study as most of studies was done on young ages less than 6 or even 1 year.

Soft tissue swelling most detected during 1st period of healing "1-2 days" from fracture. Then its detection regressed during the later periods of healing.

This come in agreement with study[11] which recorded that early soft-tissue resolution occurs between 2 and 5 days, peaking between 4 and 10 days, which concurs with the peak presence of soft-tissue swelling in our dataset at 1–2 days. Islam[5] detect it within the first week also, Prosser[7] detected soft tissue swelling in 59% of radiographs around the same time.

Regarding periosteal reaction it was highly significant detected <50 days from fracture while its detection was significantly increasing from day 1 to 35 days from fracture from 9.4% to 86% respectively. This come in agreement with study[12] which showed that periosteal reaction had a time frame similar to subperiosteal new bone formation suggested by studies[6,11] whom detected also that periosteal reaction persisted longer as in our study, Prosser[7] showed that highest detected periosteal reaction between 15-35 days, warner[9] showed it was early identified and seen at day 7 and in increasing pattern. In contrary *Islam*[5] showed that periosteal reaction not detected before 2 weeks.

Soft callus was detected between 8 to 50 days since fracture. This come in agreement with ***Islam***[5,6] who detected soft callus up to the day 35 then it started to decline, also with Prosser[7]. This in contrary to[11] in their study soft callus was identified earlier in time while Halliday[10] found that no any callus detected before 20 days.

Hard callus highly significant detected <50 days since fracture while its detection was significant increasing during the periods of healing.

This come in agreement with[5,7,11] that detected hard callus increase in prevalence with time. In contrary to Halliday[10] who didn't identify any callus before 20 days.

Bone bridging highly significant detected <50 days from fracture, on the other hand its detection was significant increasing during the periods of healing.

This come in agreement with[5,7,11] whom detected that bone bridging was increasing in prevalence with time while Warner[9] showed that bridging was first identified at day 15 & majority of cases between 15-67 days.

Bone remodelling highly significant detected< 50 days from fracture, on the other hand its detection was increasing during the periods of healing. This come in agreement with[5,7,11] who detected bone remodelling increase in prevalence with time. In contrary, Warner[9] showed that remodelling was first seen from days 51-247; the study was performed among infants less than 1 year.

To discuss each age group separately we can find some differences between groups, **the group (1 - >6 years)**, showed that remodeling last seen was from 35 -50 days. **The group (6 - >12)**, periosteal reaction was detected with high percentage of cases 38.5% during the first week & soft tissue swelling was still detected in some cases during the 3rd week of fracture**. The group (12 -18 years),** showed that periosteal reaction last detected during the period from 22-35 days & remodeling last detected during the 3rd week but it may be explained by small sample size at this age.

In other study of Prosser[7], soft tissue swelling alone is acute (<1 week old). Fractures with periosteal reaction alone are likely to be between 5 days and 2 weeks old. When periosteal reaction and soft callus are present, these findings are consistent with a fracture of

2–3 weeks old. Once hard callus or bridging appears, the fracture is 3 weeks old or older. Remodelling intimates that a fracture is more than 6 weeks old.

## Conclusion

The presence of the different radiologic features of fracture healing can indicate fracture ages. Each line represents the prevalence of each feature in the radiographs assessed. **less than 1 week**, soft-tissue swelling was the predominant feature. **(8–35 days) fractures** showed a combination of soft callus and periosteal reaction, with increasing prevalence of hard callus and bridging. **(≥36 days) fractures** showed a combination of periosteal reaction, hard callus, bridging, and remodelling.

So that appearance of each feature forms a prototype timetable of fracture healing. These data suggest that fractures with soft-tissue swelling alone are **acute fracture** (<1 week old). Fractures with periosteal reaction alone are likely to be **recent fracture** (between 8 days and 3 weeks old). Once remodelling, bridging & hard callus fractures detected then **old fracture** is expected (more than 6 weeks old).

For each age group separately, some differences were noticed between groups, **the group (1 - >6 years)**, showed that remodeling last seen was from 35 -50 days. **The group (6 - > 12)**, periosteal reaction was detected at high percentage of cases 38.5% during the first week & soft tissue swelling was still detected in some cases during the 3rd week of fracture**. The group (12 -18 years),** showed that periosteal reaction last detected during the period from 22-35 days & remodeling last detected during the 3rd week but it may be explained by small sample size at this age.

**Competing Interests:** The authors declared that they have no competing interests

**Ethics approval:** The study work was conducted after the approval of Ethical Committee, Faculty of medicine, Cairo University.

**Consent for publication:** Consent forms were given and signed by all subjects prior to participation.

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