Original Article

Outcomes of Surgical Treatment of Diaphyseal Fractures of Long Bones in Children and Adolescents through Open Reduction and Intramedullary K-Wire Fixation at Yopougon Teaching Hospital, Abidjan (Côte d'Ivoire)

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Abstract

Background: Nowadays, elastic stable intramedullary nailing is a well-accepted method for treating paediatric diaphyseal fractures, but it requires fluoroscopy that is lacking in our practice. For this reason, we have systematically performed open reduction and intramedullary Kirschner-wire fixation (ORIKF). The objective of this study was to assess ORIKF-related functional and radiological outcomes for the treatment of paediatric long bone fractures in the context of limited resources. **Patients and Methods:** From January 2010 to October 2019, 70 children (71 fractures) with an average age of 10.6 years sustaining closed displaced long bone diaphyseal fractures have been treated by ORIKF without fluoroscopy at Yopougon Teaching Hospital. They had their medical records reviewed retrospectively. Fractures were located in femur (n = 42), tibia (n = 11), humerus (n = 6) and forearm (n = 12). Pre-operative time, length of hospital stays, bone union time, nail removal time and complications were recorded. Functional and radiological outcomes were assessed according to Flynn's criteria for lower limb and the Price's criteria for upper limb. **Results:** The average follow-up time was 21 months. The results were excellent for 58 cases (81.7%), good for 8 (11.3%) and poor for 5 (7%). The average time to surgery was 10.8 days. The average in-patient stay was 11.1 days. Bone union duration was 12.3 weeks on average. The average time for nail removal was 8.1 months. According to Moroz's system, minor complications occurred in 33 cases (46.5%); major complications were observed in four cases (5.6%) and they consisted of two cases of osteomyelitis (2.8%), 1 case (1.4%) of compartment syndrome and delayed union, respectively. Complications associated with bone recovery were reported in 10 patients (14.3%). **Conclusion:** Despite the open reduction of the fractures, the results were satisfactory in 9 out of 10 patients with few major complications in a context of limited resources.

Keywords: Abidjan, children, intramedullary Kirschner-wire fixation, long bone diaphyseal fracture, open approach, operative treatment

Introduction

The operative treatment of paediatric long bone fractures included various surgical procedures such as external fixation, compression plating, rigid intramedullary nailing and elastic stable intramedullary nailing (ESIN).[1-3] The indications are based on patient's age and weight, patient condition, fracture patterns, associated injuries, the technical platform and surgeon's habits. Since nearly four decades, ESIN which needed fluoroscopy and ancillary has become a well-accepted method of surgical treatment of diaphyseal fractures of long bones in children and adolescents in developed countries because its advantages outweigh the risks.[4-9] It provides excellent results, more rapid recovery, low rate of

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complications and avoids prolonged immobilisation. Inversely, in most developing countries, treatment of these fractures is still dominated by orthopaedic approach and the rescue of traditional bone healers. Indeed, in our environment, for economic constraints and sociocultural considerations, from 30% to 58% of traumatised patients leave a health-care facility against medical advice to consult traditional bonesetters.[10,11] However, their actions lead to many ischaemic, infectious and gangrenous complications.[12,13] To avoid these complications and the heaviness of orthopaedic treatment for school age children, we sometimes gave priority to surgical treatment. However, faced with the unavailability of fluoroscopy, open reduction and intramedullary Kirschner-wire (K-wire) fixation (ORIKF) was performed when surgical treatment was indicated.[14-17] After more than 10 years of this practice, what are our therapeutic results? The aim of this study was to assess ORIKF-related functional and radiological outcomes for the treatment of paediatric long bone diaphyseal fractures in the context of limited resources.

Patients and Methods

We retrospectively reviewed the medical records of all children having consulted at the paediatric surgery unit of Yopougon Teaching Hospital at Abidjan between January 2010 and October 2019 with long bone diaphyseal fractures. The criteria for the inclusion were as follows: 6–15 age group, fractures treated exclusively by ORIKF without fluoroscopy, a follow up at least 1 year after trauma and the patient consent. The exclusion criteria included open fractures, pathological fractures, medical records of patients who lost to follow-up and those of patients who did not respond favourably to our request. Out of the first 100 patients who underwent the procedure, 70 (n = 70) with 71 fractures (one patient had bilateral fracture of humerus) met the inclusion criteria and were enrolled for this study. There were 43 boys (61.5%) and 27 girls (38.5%) with an average age of 10.6 years (range: 6–15 years) at the time of surgery. Forty-three (60.5%) patients were schoolchildren.

The fractures occurred in road traffic accident (n = 33), sports-related injury (n = 21), fall from a height (n = 9), fall from a mangoes tree (n = 5) and defenestration (n = 2). Fractures were located in femur (n = 42), tibia (n = 11), humerus (n = 6) and forearm (n = 12). Associated injuries included head trauma (n = 6), abdominal trauma (n = 3), other fractures (n = 4) and radial injury (n = 1).

ORIKF was indicated in first intention in all cases except for four forearm fractures which were treated surgically after failure of casting.

All patients were operated under general anaesthesia in the supine position on an ordinary surgical table with prophylactic antibiotic. K-wire was used for each patient. All steps of the nailing procedure were based on the three-point principles described by the Nancy team.[3,4] In the forearm, a single nail (2.2–2.5 mm diameter) was used for each bone, from the lateral distal radial and the medial proximal ulnar metaphysis. For the humerus, the two nails (2.2–2.5 mm diameter) were inserted laterally from the distal or proximal metaphysis. For femur and tibia, two K-wires were used for each bone, and nail diameter corresponded to 40% of the canal diameter at its narrowest portion. A long-leg cast was applied in some femoral and tibial fractures in case of instability after ORIKF procedure. Patients with lower limb fractures were mobilised non-weight-bearing by crutches, and upper limb fractures were supported in a Mayo clinic sling for 10–15 days. The duration of non-weight-bearing was difficult to evaluate. Progression of union at fracture site was assessed radiologically. Bone union was obtained when callus involved at least three or four cortices on the anterior-posterior and lateral X-rays.

Data collected included pre-operative time to surgery, post-operative immobilisation, length of hospital stay, bone union time and time to nail removal. Complications and outcome were also recorded. Complications were classified according to Moroz *et al*.[7] system. The infection was defined by the presence or not of suppuration or oozing, the isolation or not of a germ with or without sign of osteolysis at the radiography. The presence of sign of osteolysis on the radiography defined the osteomyelitis. The germs were searched by the standard techniques on Petri's boxes.

Functional outcomes were assessed according to Flynn *et al*.[8] scoring in lower limb and as Price criteria[18] for upper limb [Table 1]. The data were processed using Epi Info™ 6.04. CDC Atlanta, Georgia (USA) and Excel 2010 (Microsoft® Office 2010).

Results

At the mean follow-up of 21.2 months (range: 13–53 months), all the fractures healed, and the results were excellent in 58 cases (81.7%) [Figure 1], good in 8 (11.3%) and poor

Table 1: Clinical outcomes scores

	Excellent	Good	Poor
Flynn's scoring criteria[8]			
Limb length discrepancy (cm)	<1	<2	>2
Angulation (°)	<5	5-10	>10
Pain	Absent	Absent	Present
Complications	Absent	Mild	Major/extend morbidity
Price's scoring criteria[18]			
Range of motion (supination and pronation) (°)	Full	<30	>30
Complications	Absent	Minor or resolving post-operative complication	Major post-operative complications (infections, delayed union, and compartment syndrome)

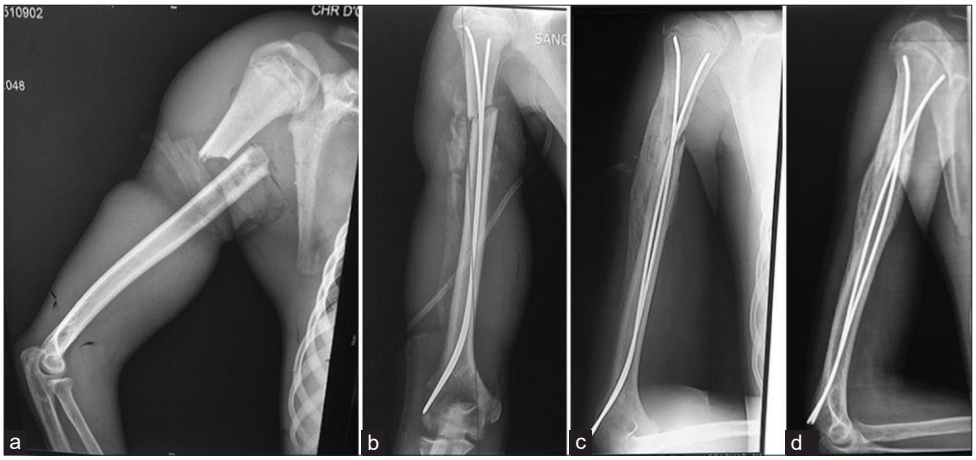


Figure 1: A 14-year-old boy sustained a third proximal fracture of humerus. (a) Pre-operative radiograph. (b) Post-operative radiograph. (c) Twelve weeks radiograph show bone union. (d) one year radiograph shows complete union

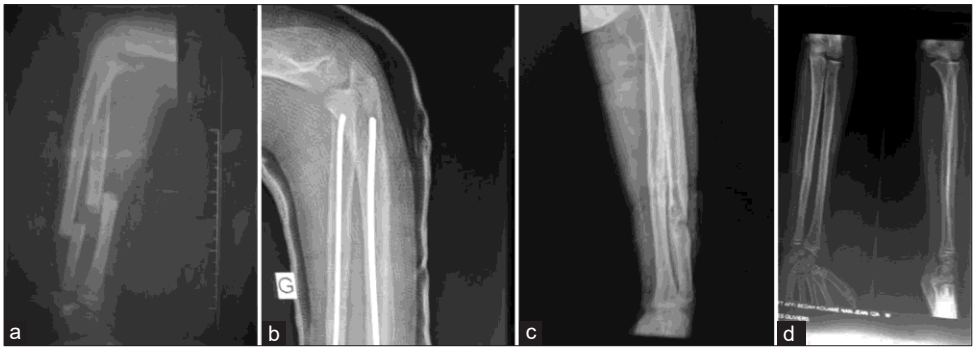


Figure 2: A 11-year-old boy sustained fracture of both bones of forearm. (a) Pre-operative radiograph. (b) X-rays at 11 weeks showing union of the radius and osteomyelitis of the ulna. (c) X-rays aspect after nail removal. (d) X-ray at 17 months showing complete consolidation

Table 2: Outcomes of fractures

	Femur, *n* (%)	Tibia, *n* (%)	Humerus, *n* (%)	Forearm, *n* (%)	Total, *n* (%)
Excellent	35 (83.3)	9 (82)	6 (100)	8 (67)	58 (81.7)
Good	5 (12)	1 (9)	0	2 (16.5)	8 (11.3)
Poor	2 (4.7)	1 (9)	0	2 (16.5)	5 (7)

in 5 (7%) [Table 2]. The average time to surgery was 10.8 days (range: 2–23 days). None of the patients was transfused peroperatively. Post-operative casting was applied in seven cases (12%): femur ($n = 4$) and leg ($n = 3$). The average in-patient stay was 11.1 days (range: 3–46 days). Bone union time was 12.3 weeks (range: 7–37 weeks) on average. The nails were removed after an average of 8.1 months (range: 5–15 months), but six patients still have their nails for unknown reasons.

Minor complications occurred in 33 cases (46.5%) [Table 3]. We found superficial skin infection at nail entry site in two cases and at surgical site in five cases. These infections were healed by dressing and oral antibiotics.

Osteomyelitis was noted in two cases [Figure 2]. This deep infection was due to *Staphylococcus aureus* and was treated by adapted oral antibiotic and debridement.

One patient with closed forearm fracture developed compartment syndrome the day after IKFOR. We performed fasciotomy and closed the incision 8 days later.

Four cases of angular malunion were found: Three cases of varus (8°, 10°, and 17°) and one valgus (10°). Three had leg length discrepancy, and all was <15 mm. Knee stiffness was noted in three cases and needed physiotherapy.

The scar was not a concern for many parents, and pre-operative radial neurapraxia recovered within 4 months after injury. Rotational malalignment and nail migration were not observed. No complications were associated with the nail removal procedure. At the final follow-up, all the patients with lower limb fracture had full range motion on knee.

Discussion

The treatment of displaced long bone diaphyseal fractures in school age children has remained a constant challenge for the orthopaedic surgeons in developing countries because of the limited platform. In our practice, we have systematically performed ORIKF that allow us the visual control of the fracture reduction and the nails passage. Our attitude was explained by most reasons: (1) The unavailability of fluoroscopy; (2) It avoids the rescue of traditional bonesetters that are consulted

Table 3: Distribution of complications according to Moroz' system[7]

Type of complications (% of 71 total)	Femur	Tibia	Humerus	Forearm
Minor complications (*n*=33; 46.4%)				
Superficial infection at surgical site	3	-	-	-
Superficial infection at nail entry site	2	1	-	1
Skin irritation with pain	4	1	1	-
Knee stiffness	3	-	-	-
Malunion	3	1	-	-
Limb length discrepancy <2 cm	3	-	-	-
Cheloid scar	3	2	2	1
Delayed union	-	1		1
Major complications (*n*=4; 5.7%)				
Osteomyelitis	1	-	-	1
Compartment syndrome	-	-	-	1
Delayed union	-	1	-	-

by nearly 58% of the traumatised patients who leave a health facility against medical advice[10,11] and (3) it leads us to avoid the heaviness of traction followed by cast immobilisation. Indeed, most parents of our patients have informal sector activities without health insurance. Lengthy hospitalisations cause financial hardship for families as well as high hospital bed occupancy rates; (4) the long time to surgery favoured the formation of bony callus. This delay was explained by the fact that operating room entrance fees, K-wires and pharmaceutical products were bought by the parents and the multiple postponements of the surgical intervention (only one operating room was dedicated for all emergencies for five surgery units in our hospital).

Unlike us, most authors supported that open reduction was required after failure of closed reduction due to soft-tissue interposition,[19-21] and the rate of conversion varied from 38% to 74.4% in the literature.[19,22]

To our knowledge, there is the scarcity of similar studies in the literature apart from our previous works[14,15] and that of Komlatsè *et al*.[17] in Togo.

In response to our questions, our management achieved satisfactory functional and radiological results with few major complications despite our difficult working conditions. Komlatsè *et al*.[17] in the same context showed satisfactory results. Although our attitude cannot be generalised with regard to current therapeutic standards, we believe that our results can be superimposed on those of studies having benefited from fluoroscopy in terms of functional outcomes and complications.[5,7,20,23]

In practice, we used only K-wires because of their easy availability and low cost. Sometimes, we also used an alternative instrument as did Sharma *et al*. in India.[24] We agreed with Komlatsè *et al*.[17] that our working conditions are discouraging in sub-Saharan area, and they make difficult to promote the ESIN in our context. The ancillary and new ergonomic instruments, precurved nails and end caps used by most authors in developed world to reduce surgery time and to prevent certain complications were unavailable in our context.[4,5,19,25]

Pre-operative delay in this series (10 days) and that in the study conducted by Komlatsè *et al*. (21 days)[17] was late in comparison to the western scenario. The average length of pre-operative delay was 4.9 and 6.4 days, respectively in the comparative study of Shah *et al*. in USA.[9] Eighty percent of the patients in the study conducted by Nisar *et al*.[1] in the UK and Zivanovic *et al*.[26] in the USA were operated within 24 h. These differences of pre-operative time are likely reflective of the level of development of the health-care system.

Post-operative immobilisation has variably been used after internal fixation with flexible nails. It was reported in up to 52% in the previous study.[1,27] Ligier *et al*.[4] did not use any post-operative immobilisation contrary to our study and those of Mohammad *et al*. (10%)[20] and Bhuyan and Mohan Singh (17.5%).[2]

The mean length of hospital stay in this study was higher than those reported in the previous studies: Shen *et al*. 3.9 days,[28] Onta *et al*. 5.7 days[29] and Mohammad *et al*. 2.5 days,[20] but it was less than the one in the study conducted by Komlatsè *et al*. 54 days[17] at Tokoin Teaching Hospital (Togo). The long delay before surgery was the main explanation of this length of hospitalisation.

Timing of nail removal after fracture union has not been uniform in the previously published series and there are no clear guidelines in the literature. Early removal has led to occasional complications; for this reason, most authors have particularly recommended nail removal after fracture healing at 6 months to 1 year following surgery.[6,8,22]

Overall, the complication rate in the current study is superimposed to those reported by several studies after closed reduction and ESIN from 0% to 69%.[5,8,22,30]

Minor complications predominated in this series and none of them required additional unplanned surgery. Similarly, high incidence of minor complications has been observed by Moroz *et al*.,[7] Shah *et al*.[9] and Nisar *et al*.[1]

For Kong *et al*., there are no significant difference between ESIN by closed or open reduction in terms of complications.[31]

The most common complication after ESIN is skin irritation due to nail protrusion.[6,7,19,23,32,33] To avoid these problems, certain authors recommend using protective caps (end cap) or to cut nail shortly.[1,3,25,33]

Although open reduction avoids to radiation, it exposes to the high risk of bleeding and infection.[34] In this study, two cases of

osteomyelitis were observed. The rate of this deep infection has been reported in nearly 2% of cases by several authors.[3,5,31,35-37] In a large meta-analysis including 835 patients, Fanelli *et al*.[35] have reported a major complications rate of 6.8% with eight cases (1%) of osteomyelitis.

The other disadvantage of open reduction was scar and delay of bone union. In our context, most of the parents did not consider the length and aspect of the scar. This scar was smaller than that obtained after compression plating which has the disadvantages of larger soft-tissue dissection, a large scar and a second major operation for the removal of the plate.

According to Truntzer *et al*.,[38] open reduction increases healing time as much as 2 weeks. This was certainly due to the drainage of fracture haematoma, and the injury of the periosteum and muscle of fracture end, which leads to insufficient blood supply.[31] We are aware that union time has to be taken with caution because most patients attended the follow-up visit at a later date than scheduled. Radiological union would have taken place long before X-rays were taken spuriously, inflating the union time in this series.

The cases of malunion and leg length discrepancy encountered did not cause any clinical and functional disability.

Depending on the source, between 1% and 7.5% of compartment syndrome after ESIN was reported in the literature.[22,35] This complication was observed in one case in our series, and it had leaded to one case of amputation in the series of Fanelli *et al*.[35]

Other complications such as nail migration, nail breakage, tendon rupture, rotational angulation, and refracture after nail removal were not observed in our study.

Despite the satisfactory results obtained, this study lacks the power to change the surgical habits of paediatric surgeons in developing countries. This study has several limitations. The study has a retrospective assessment of surgical treatment and the difficulties in data collection. The sample size of both bone fractures was small. The difficulties in the follow-up of patients were due to the lack of calling system for follow-up visits. There is no respect of appointments and medical instructions by the patients. For this reason, the duration of non-weight-bearing was difficult to evaluate. Outcomes according to the patient' weight have not been studied. We did not have a control group nor did we compare other methods of treatment. The scarcity of similar studies in the literature limits the relevance of our results.

Conclusion

ORIKF yielded satisfactory functional and radiological results in more than 90% of cases. Open reduction did not lead to more deep infections. Through the results in the current study, ORIKF can be considered as one option for treating paediatric long bone fractures in developing countries, until specialised equipment is available. However, the three-point principle of ESIN must be rigorously applied. This approach can lead to avoid the rescue of traditional bonesetters.

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Conflicts of interest

There are no conflicts of interest.

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