Original article

Surgical treatment of femoral diaphyseal fractures in children using elastic stable intramedullary nailing by open reduction at Yopougon Teaching Hospital


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A B S T R A C T

Introduction: Elastic stable intramedullary nailing (ESIN) has transformed children's femoral shaft fracture treatment, but this technique requires an image intensifier. Without it, open reduction is used to check fracture reduction and pin passage. The aim of this study was to describe our techniques and to evaluate our results at the middle term.

Hypothesis: The open reduction and ESIN technique provides satisfactory results with few major complications.

Patients and methods: This was a retrospective study that focused on femoral diaphyseal fractures treated in the pediatric surgery unit at Yopougon Teaching Hospital (Abidjan, Côte d'Ivoire) between January 2007 and December 2013. Twenty children older than 6 years of age who underwent open reduction and ESIN without image intensifier assistance were included. Functional outcomes were assessed using Flynn's criteria. Postoperative complications and sequelae were recorded.

Results: At the 16-month follow-up, the results were excellent in 11 (55%) cases, good in eight (40%), and poor in one (5%) case. The mean duration of surgery was 71 min (range, 57–103 min). The mean time for bone healing was 11.6 weeks (range, 7–15 weeks) and the average time to nail removal was 6 months. Complications included wound infection (n = 3), skin irritation (n = 3), knee stiffness (n = 2), malunion (n = 3), scar (n = 5), and leg length discrepancy (n = 3).

Discussion: Open reduction and ESIN yielded satisfactory results with few major complications. This method could be an alternative in low-income countries where the image intensifier is often unavailable.

Level of evidence: Level IV retrospective study.

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1. Introduction

Femoral fractures account for 2% of all fractures in children [1,2] and are a frequent cause of morbidity in pediatric surgery. Treatment of diaphyseal fractures of the femur (DFF) in children has progressed, most recently with elastic stable intramedullary nailing (ESIN), which has made it possible to arrest the complications, severity, and poor results of orthopaedic treatment. This technique, performed percutaneously with the image intensifier via a minimally invasive approach when the fracture cannot be reduced, provides excellent results in many of the series reported in the literature [3–5]. The ESIN technique was introduced in our hospital in the 2000s. After the study conducted by Odéhouri et al. [6] and the failure of our technical platform, we systematically performed ESIN using open reduction. We hypothesized that ESIN using open reduction would give good results with few major complications. The objective of this study was to describe the technical features and assess the mid-term results of DFF treatment with ESIN in our context.

2. Patients and methods

This was a retrospective study on DFFs treated from January 2007 to December 2013 in the Pediatric Surgery Department of the Yopougon University Hospital (Abidjan, Côte d'Ivoire). Included in the study were all the medical files of children who underwent ESIN using open reduction and with regular follow-up lasting a minimum of 12 months. We excluded all open fractures,
pathological fractures, children under 6 years of age, and cases treated orthopaedically. Six patients lost to follow-up after removal of the osteosynthesis material or who had less than 12 months of follow-up were not included in the study. Twenty (77%) patients out of 26 were retained: 13 boys and seven girls with a mean age of 10.3 ± 3.18 years. The fractures occurred in road traffic accidents in 18 cases and a fall from a height in two cases. The associated injuries were head trauma (n=2), abdominal trauma (n=2), and bone lesions (n=3). The fractures occurred in the upper third of the femoral shaft in eight cases (40%), and in the middle and lower thirds in six cases (30%) each. There were 12 transverse (60%), six oblique (30%), and two spiral (10%) fractures. Before ESIN, all patients underwent preoperative cutaneous axial traction. This preoperative time allowed parents to purchase the surgical kit and have the wires sterilized by the paramedical team. ESIN was indicated immediately in all cases. Seventeen (85%) of the patients underwent surgery by two senior surgeons and three (15%) by a junior surgeon. The nail/medullary canal diameter was 40%.

All the patients were operated using the following surgical technique:

- under general anesthesia, in the dorsal decubitus position, on an ordinary surgical table, and with no image intensifier;
- the wires were curved with a bent tip and the other tip was marked with a felt pen at the concavity (Fig. 1);
- two 2- to 3-cm incisions were made on the thigh, one lateral and the other medial, three finger widths above the knee joint space;
- the wires were put in place using a T-handle up to the fracture site;
- the posterolateral approach was used to access fracture site was the wires were inserted up to the fracture extremity of the bone fragment;
- the fracture was reduced and maintained with a clamp;
- the wires were then pushed into the opposite fragment and they were oriented according to the initial marking;
- the wires were bent, cut, and inserted under the skin;
- the wound was closed over suction drainage.

In three cases, a long-leg cast was made. The drain was removed on the third day. Partial weightbearing was authorized after 3–4 weeks. Bone union was obtained when osseous callous formation involved at least three of the bone cortices on the AP and lateral X-rays. The duration of surgery, the duration of the hospital stay, the time to bone union, and any complications (infection, reoperation, wire migration, skin irritation, knee stiffness, malunion, limb length discrepancy [LLD], keloid scars) were recorded. The results were evaluated according to the criteria according to Flynn’s criteria [5] (Table 1). The data were processed using Epi info 2008 software.

### 3. Results

At the mean follow-up of 16 ± 7.85 months, the results (Fig. 2) were excellent in 11 (55%) cases, good in eight (40%) cases, and poor in one (5%) case. The mean duration of the intervention was 71 min (range, 57–103 min) and none of the patients was transfused. The mean hospital stay before ESIN treatment was 7 days (range, 3–16 days) and after ESIN 5.7 days (range, 5–22 days). The mean time to bone union was 11.6 weeks (range, 7–15 weeks) and the wires were removed during the 6th month on average, ranging from 5 to 9 months.

The complications are summarized in Table 2: infection of the surgical wound (n=3), skin irritation (n=3), and knee stiffness (n=2). As for the surgical site infections, no bacteria were identified and they were treated with local care and probanthic anti-—Staphylococcus antibiotic therapy because of its frequency in this type of situation. No cases of infection of the wire entry site, wire breakage, refraction after wire removal, or rotational malunion were observed. Three cases of angular malunion were found, two of which were varus (8° and 17°) and one valgus (10°). All LLDs were less than 15 mm. Knee stiffness comprised limitation of flexion assessed at 60° and 70°. In all cases, this stiffness regressed after physical therapy.

### 4. Discussion

The limitations of this study are related to the sample size, the absence of a comparison with other techniques, and the fact that all the patients were treated with a single method. The DFF treatment of each child depended on several factors, including the child’s age, the fracture site, the type of fracture line, the technical platform, the surgeons’ habits, and the patients’ socioeconomic conditions [7–9]. Although conservative FFD treatment in children under 6 years of age is accepted by the majority of authors, the ideal treatment of children over 6 years of age does not meet agreement [1,10–14]. Beyond 6 years of age, the surgical treatment advocated by most authors recommends two types of fixation: external and internal fixation (plate and screw fixation, interlocked nailing, rigid intramedullary nailing, and ESIN) [1,3,4,7–9,11,12,15]. After the excellent results reported by Ligier et al. [3], the ESIN technique has rapidly gained in popularity throughout the world [16,17] to become the gold standard of FFD treatment [1,18]. In case the fracture cannot be reduced by muscle interposition, the technique performed through the percutaneous or a minimally invasive approach can boast several advantages: the short surgical time, the early ambulation of the patient, the short hospital stay, the short absence from school, and the excellent results [4,15]. In our context, the lack of an image intensifier made reduction through a systematic approach to the fracture site the only alternative when ESIN was indicated. On the technical level, we used Kirshner wires, as did other authors [7,11,13,15,19], because of their low cost and availability, instead of Nancy wires or the titanium wires proposed by Lascombes et al. [4] and Flynn et al. [5]. Other authors such as Park et al. [16] in Colombia used locally made wires. Despite the approach to the fracture site, reduction was often difficult when malunion had begun, especially in certain older children, explaining the long duration of the intervention. The surgical time was much longer than that reported by Lascombes et al. (42.4 min) [4], Chitgopkar (40 min) [19], and Qidwai and Khattak (40 min) [15]. Their short surgical times could be explained by their use of an

| Table 1 Evaluation after ESIN according to Flynn et al. [6] criteria. |
|-----------------------------|----------------|-----------------------------|
| Excellent | Good | Poor |
| Limb length discrepancy | <1 cm | <2 cm | >2 cm |
| Malunion | 5° | 10° | >10° |
| Pain | Absent | Absent | Present |
| Complication | Absent | Minor or resolved | Major and/or long-lasting morbidity |
image intensifier, their long experience with the ESIN technique, and the existence of adapted material.

After nailing, a long leg cast was made in three cases. Associating ESIN with a cast is reported in 0–52% of cases [13,20]. Evacuation of the perifracture hematoma could explain the long time to bone union compared to the mean 8 weeks reported by some authors after ESIN via the percutaneous approach [1,15].

Concerning the therapeutic results according to the criteria described by Flynn et al. [5], our practice with the approach at the fracture site made it possible to obtain results similar to other authors [1,4,5,7,19,21]. The complication rates reported after ESIN in several studies varied from 0 to 60% [5]. These complications are dominated by pain related to skin irritation caused by the protuberance of the wires [2,4]. According to the distribution of complications after ESIN described by Moroz et al. [22], our practice exposed patients to very few major complications.

The fracture site approach exposes the patient to the greater risk of infection found in the present series, as in most series: these were superficial infections that evolved favorably with adapted antibiotics.

The knee stiffness observed in our series was also reported by Metaizeau et al. [8] in a study in which stiffness may have resulted from vastus muscle irritation caused by the wire ends. To prevent these irritations and wire migration, Nectoux et al. [18] used “end caps,” making it possible to place the wires and protect the muscles and skin.

Nisar et al. [20] recut the wires when they were protuberant. These authors recommended that the extraosseous and subcutaneous part be less than 1–1.5 cm [4,15,20].

LLD after ESIN has been reported in 8–20% of cases [3,16], which were shortening or overgrowth of the injured limb [3,5,16]. Overgrowth may be due to hyperactivity of the periosteum around the fracture site and remodeling. Shortening could be explained by the

Table 2
Patient characteristics.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (years)</th>
<th>Site</th>
<th>ESIN type</th>
<th>Complications</th>
<th>Bone union (weeks)</th>
<th>Follow-up (months)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>6</td>
<td>Mid 1/3</td>
<td>Retrograde</td>
<td>Infection</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>8</td>
<td>Low 1/3</td>
<td>Anterograde</td>
<td>–</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>15</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>LLD 10 mm</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>14</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>–</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>15</td>
<td>Low 1/3</td>
<td>Anterograde</td>
<td>Skin irritation</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>8</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>Keloid scar</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>7</td>
<td>Low 1/3</td>
<td>Anterograde</td>
<td>–</td>
<td>14</td>
<td>15.5</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>8</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>Knee stiffness 70'</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>14</td>
<td>Low 1/3</td>
<td>Anterograde</td>
<td>LLD 10 mm, keloid scar, infection, varus 17'</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>10</td>
<td>Mid 1/3</td>
<td>Retrograde</td>
<td>–</td>
<td>15</td>
<td>12.5</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>14</td>
<td>Low 1/3</td>
<td>Anterograde</td>
<td>Keloid scar, infection</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>6</td>
<td>Mid 1/3</td>
<td>Retrograde</td>
<td>Skin irritation</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>7</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>–</td>
<td>14.5</td>
<td>15</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>9</td>
<td>Low 1/3</td>
<td>Anterograde</td>
<td>Valgus 10'</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>13</td>
<td>Mid 1/3</td>
<td>Retrograde</td>
<td>LLD 7 mm</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>9</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>Keloid scar</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>12</td>
<td>Mid 1/3</td>
<td>Retrograde</td>
<td>Skin irritation, knee stiffness 60'</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>9</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>Varus 8'</td>
<td>9</td>
<td>49</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>13</td>
<td>Mid 1/3</td>
<td>Retrograde</td>
<td>Keloid scar</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>9</td>
<td>Upp 1/3</td>
<td>Retrograde</td>
<td>–</td>
<td>10</td>
<td>22</td>
</tr>
</tbody>
</table>

type of fracture, with incomplete reduction or instability at the fracture site.

The causes of malunion reported by Lascombes et al. [23] include the patient’s weight, the type of fracture, the use of wires of different sizes, or reduction failure. Long-term monitoring is required to evaluate these cases of misalignment and LLD at bone maturity.

5. Conclusion

ESIN with an approach via the fracture site provides good results with few major complications. The use of Kirschner wires is reliable on condition that basic principles are respected. Experience as well as equipment and material adapted to the operating room should save time and decrease the complication rate. This technique could be an alternative in developing countries where the lack of an image intensifier is frequent.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References