

# Rigid Nail Fixation for Treatment of Femur Fractures in Children Aged 6 to 12 Years: A Review

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## ABSTRACT

Although femoral shaft fractures are common in children, treatment using rigid intramedullary nail fixation remains controversial owing to concerns of avascular necrosis (AVN) and disruption of growth of the proximal femur. We examined studies on AVN complications and proximal femur deformity after rigid nail fixation in children aged 6 to 12 years. Of the 13 studies included, nine had no incidents of AVN or clinically significant proximal femur deformity using a greater trochanter entry point. Four studies showed cases of AVN or proximal femoral deformity in patients treated with intramedullary nails through a starting point at or near the piriformis fossa or the tip of the greater trochanter. The findings of this review suggest that antegrade rigid intramedullary nailing may be an acceptable treatment option for femoral shaft fractures in children aged 6 to 12 years, especially when the lateral aspect of the greater trochanter is used as the entry point. Results of future research are needed on age-related outcomes and complications of rigid intramedullary nailing fixation of femoral shaft fractures in children.

**Keywords:** Femoral Fractures, Femoral Fixation, Intramedullary, Pediatric, Femur

## INTRODUCTION

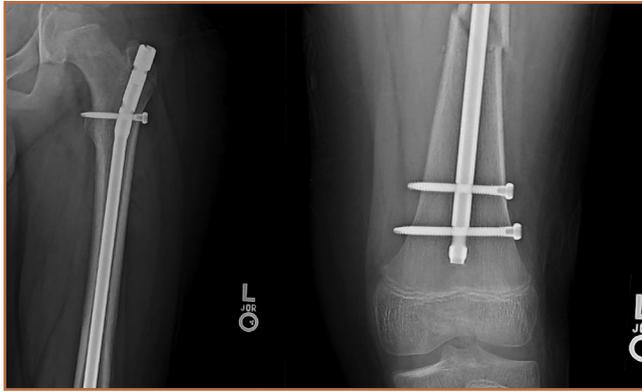
Femoral shaft fractures are common injuries in children (Figure 1). Despite the frequency of occurrence, treatment remains controversial especially in younger and larger patients who are skeletally immature. Studies remain somewhat limited in this population, particularly in children between the ages of 6 to 12 years. In adults, the most common treatment of these fractures is operative fixation using rigid intramedullary nails. This type of fixation allows for early mobilization and stable fracture fixation; however, its use in skeletally immature patients remains controversial owing to concerns of avascular necrosis (AVN) and disruption of growth of the proximal femur.



**Figure 1.** Preoperative radiograph of an 11-year-old girl, showing a femur shaft fracture with open physes.

In children, common operative interventions include intramedullary nail fixation, submuscular plating, and external fixation—each with a range of risks and benefits. First, flexible intramedullary nailing may not provide adequate fixation in children aged 6 to 12 years if they have length-unstable fractures, rotationally unstable fractures, or are obese.<sup>1-5</sup> Additionally, very proximal and distal fractures may not be adequately stabilized with flexible intramedullary nails.<sup>6</sup> Next, submuscular plate fixation provides the benefit of allowing an anatomic reduction; however, it often requires a larger incision as well as removal of the implant owing to risk of stress shielding, leg length discrepancy, and screw prominence.<sup>7-8</sup> In 2013, May et al<sup>8</sup> found a 6% unplanned reoperation rate for children with femoral shaft fractures treated with plate fixation. External fixation is another treatment option that is minimally invasive; however, there is a high risk of complications when using an external fixator for treating femoral shaft fractures in children.<sup>9</sup> Complications include pin infections and the risk of refracture after removal of the pins and fixator.<sup>10-11</sup>

The purpose of this review was to examine the studies that focused on the complications of AVN



**Figure 2.** Postoperative radiographs of the same girl in Figure 1 after she underwent antegrade rigid intramedullary nail fixation.

and proximal femur deformity after rigid nail fixation for treatment of femoral fractures in children aged 6 to 12 years. After accessing the potential risks and benefits of these three treatment options, we felt that locked rigid intramedullary nail fixation could be a reasonable treatment option for these patients (Figure 2). Antegrade nailing is the focus of this review because retrograde rigid intramedullary nail fixation is not usually performed in skeletally immature patients owing to the high risk of distal femur physis closure and subsequent limb length discrepancy. Additionally, the age range of 6 to 12 years was chosen for this review because of the controversy surrounding this population and fixation of femur fractures. Multiple options are available for treatment in this age group, whereas there is less debate about the best mode of fracture stabilization or fixation for patients younger than 6 years or older than 12 years.

## METHODS

We searched for articles that were focused on rigid intramedullary nail fixation for treating femoral shaft fractures in children aged 6 to 12 years. Articles from January 1, 1996 to December 31, 2017 were included. Of the 290 articles found during our search, 13 relevant articles were identified and included in our review.<sup>12-24</sup> We used several databases such as PubMed, Web of Science, and Cumulative Index to Nursing and Allied Health Literature. The MeSH terms used were “femur fracture,” “femoral fractures,” and “fracture fixation, intramedullary” including children aged 6 to 12 years. No studies were identified that explicitly focused on children aged 6 to 12 years; therefore, all studies that examined children in this general age range were included. Articles were excluded if they were case reports, did not examine long-term complications, did not include rigid intramedullary nail fixation, or included adult patients.

## RESULTS

Table 1 shows the details of each article included. Nine articles had no incidents of AVN or proximal femoral deformity, and most of these described a greater trochanter tip or lateral greater trochanter entry point.<sup>12-20</sup>

In 2000, Townsend and Hoffinger<sup>12</sup> studied 34 patients between the ages of 10 to 17 years who underwent intramedullary nail fixation using a greater trochanter tip entry point. There were no cases of AVN or deformity. In 2002, Gordon et al<sup>13</sup> looked at nine patients between the ages of 8 to 11 years who underwent femoral lengthening over a nail. There were no cases of AVN or proximal femur complications using a lateral greater trochanter entry point. In 2003, Gordon et al<sup>14</sup> performed another study that found no cases of AVN. The study comprised 22 patients between the ages of 7 to 13 years who underwent intramedullary nail fixation using a trochanteric entry point. This resulted in clinically important femoral neck narrowing, valgus femur changes, or proximal femur changes. In 2004, Gordon et al<sup>15</sup> performed a third study and found the same results in 15 patients between the ages of 8 to 17 years who were treated with intramedullary nail fixation through lateral trochanteric entry point.

In 2009, Keeler et al<sup>16</sup> reviewed 78 children treated with intramedullary nail fixation through a lateral trochanteric entry point and reported no incidents of AVN or proximal femur deformity. In 2012, Miller et al<sup>17</sup> reviewed 17 skeletally immature patients between the ages of 7 to 11 years, in which all patients had open physes and trochanteric apophyses at the time of operative treatment. The patients were treated with a rigid intramedullary nail using a lateral trochanteric entry point, and the authors found no incidents of AVN or proximal femur deformity. In a review of 23 children aged 9 to 15 years, Elgohary and El Adl<sup>18</sup> found no cases of AVN or proximal femoral deformity using a greater trochanter entry point. Shahabuddin et al<sup>19</sup> examined 18 patients aged 6 to 13 years treated with Surgical Implant Generation Network (SIGN) Pediatric nails and SIGN-Fin nails without any complications. In a 2015 retrospective review, Herrera-Soto et al<sup>20</sup> reported findings of 10 patients aged 9 to 14 years with subtrochanteric femur fractures. The patients were treated with intramedullary nail fixation with a lateral greater trochanter entry point, and no major complications were reported.

We encountered four papers that described patients with AVN or proximal femur deformity.<sup>21-24</sup> MacNeil et al<sup>21</sup> found that rates of AVN varied significantly based on entry site, with rates of 2% for the piriformis fossa (5 of 239 patients), 1.4% for tip of the greater trochanter (2 of 139 patients), and 0% for lateral greater trochanter entry (0 of 80 patients). The patients who were developing AVN with piriformis fossa nail entry were aged 10, 12, 13, and 13 years, with the fifth patient's age unspecified. The patients who developed AVN after rigid nail fixation with tip of greater trochanter entry were aged 11 years and one age was unspecified. Furthermore, a study by Letts et al<sup>22</sup> had one case of AVN in a group of children aged 11 to 17 years, with 10 of the children under the age of 13 years. The case of AVN was in a 13-year-old patient who underwent intramedullary nail fixation through the piriformis fossa.

**Table 1.** Description of articles

Author	Year	Description <sup>a</sup>	Entry point	AVN or PFD <sup>a</sup>
Townsend and Hoffinger <sup>12</sup>	2000	34 aged 10-17 years	Tip of greater trochanter	None
Gordon et al <sup>13</sup>	2002	Nine aged 8-11 years <sup>b</sup>	Lateral greater trochanter	None <sup>h</sup>
Gordon et al <sup>14</sup>	2003	22 aged 7-13 years	Lateral greater trochanter	None
Gordon et al <sup>15</sup>	2004	15 aged 8-17 years	Lateral greater trochanter	None
Keeler et al <sup>16</sup>	2009	80 fx in patients aged 8-18 years	Lateral greater trochanter	None
Miller et al <sup>17</sup>	2012	17 aged 7-11 years	Lateral greater trochanter	None
Elgohary and El Adl <sup>18</sup>	2014	23 aged 9-15 years	Tip of greater trochanter	None
Shahabuddin et al <sup>19</sup>	2015	18 aged 6-13 years <sup>c</sup>	Lateral greater trochanter	None
Herrera-Soto et al <sup>20</sup>	2015	10 aged 9-14 years <sup>d</sup>	Lateral greater trochanter	None
MacNeil et al <sup>21</sup>	2011	458 aged 6-18 years <sup>e</sup>	Piriformis fossa, tip of greater trochanter, lateral greater trochanter	5 AVN with piriformis entry, 2 AVN with tip of greater trochanter entry
Letts et al <sup>22</sup>	2002	54 aged 11-17 years	Piriformis fossa, greater trochanter <sup>f</sup>	1 AVN
Buford et al <sup>23</sup>	1998	50 aged 10-16 years	Lateral and posterior to the piriformis fossa <sup>g</sup>	2 AVN <sup>i</sup>
Beaty et al <sup>24</sup>	1994	17 aged 10-13 years	Piriformis fossa	1 AVN <sup>i</sup> , 1 PDF

AVN, avascular necrosis; fx, fractures; PFD, proximal femur deformity.

<sup>a</sup>Numbers represent number of patients unless otherwise stated.

<sup>b</sup>Femoral lengthening over intramedullary nailing.

<sup>c</sup>Surgical Implant Generation Network (SIGN) pediatric nail and SIGN-Fin nail.

<sup>d</sup>Subtrochanteric femur fractures treated with intramedullary nailing.

<sup>e</sup>Systematic review including 19 articles.

<sup>f</sup>Location unspecified.

<sup>g</sup>Medial greater trochanter.

<sup>h</sup>None that were clinically significant.

<sup>i</sup>Asymptomatic.

AVN sometimes developed without symptoms. In a prospective study, Buford et al<sup>23</sup> described 54 children between the ages of 11 to 17 years. He found two cases of AVN treated with intramedullary nail fixation through an entry point described as more lateral and posterior than piriformis fossa. One of these cases was in a 12-year-old boy who also had evidence of AVN on the uninjured and unoperated side, raising the possibility of an idiopathic source. The other case was in a 10-year-old girl who developed signs of AVN as found on magnetic resonance imaging.<sup>23</sup> The patients with AVN had no symptoms. Out of 17 children under the age of 13 years who were treated with intramedullary nail fixation through the piriformis fossa, Beaty et al<sup>24</sup> also reported one patient without AVN symptoms. They also found one patient with an increase in articulothoracic distance that was similarly asymptomatic.

## CONCLUSION

We reviewed the available studies on rigid nail fixation for treating skeletally immature children with femur fractures, particularly focusing on studies

that included children as young as 6 years. A total of nine of thirteen papers found no incidents of AVN or clinically significant proximal femur deformity using a greater trochanter entry point (especially a lateral greater trochanter entry point).<sup>12-20</sup> The remaining four studies described AVN or proximal femoral deformity in patients who were treated with intramedullary nails through a starting point at or near the piriformis fossa or the top of the greater trochanter.<sup>21-24</sup> There was a lesser rate when using a starting point at the tip of the greater trochanter.

Other treatment options for femoral shaft fractures in children aged 6 to 12 years include external fixation, submuscular plating, and flexible intramedullary nail fixation. Each of these treatment options have their own risks and benefits. This findings of this review suggest that rigid nail fixation in children aged 6 to 12 years may be an acceptable operative intervention for treating femoral shaft fractures, particularly when the lateral aspect of the greater trochanter is used as the entry point.

Notably, we found no studies that solely focused on children aged 6 to 12 years; additionally, the studies

that did include these ages also reported on older ages. Considering that most of these studies did not report data divided by age group, we were unable to separate the data regarding children aged 6 to 12 years from the data pertaining to the older children. Future studies that solely focus on patients aged 6 to 12 years would provide more information regarding the treatment outcomes of this age group.

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