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Factors Affecting Long Term Outcome of Rigid Intramedullary Nailing of Lower Limb Diaphyseal Fractures in Older Children

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Abstract

Introduction: Our study aims to assess long term treatment outcomes in children over 10 years of age treated with rigid Surgical Implant Generation Nail (SIGN) and the factors influencing outcomes specifically limb shortening and squat and smile grade. **Materials and Methods:** This is a retrospective study. Data from 21 patients aged between 12 to 18 years with fractures of the shaft of the femur or tibia treated with SIGN intramedullary nails over a 48-month period was analysed. Data were collected from the SIGN online database, patient case notes and radiographs. Patients were followed up for a period of 2 to 4 years. Patient's variables such as age, sex, weight, mechanism of injury, history of previous surgery, associated injuries, time to surgery, co-morbidities were analysed. Fracture type, AO classification, time to union, implant size and complications were analysed. Limb length discrepancy and squat and smile sign scoring were the outcome measures. Statistical analysis was performed using the SPSS. Statistical significance was set at $p < 0.05$. **Results:** The age range was 12 to 18 years with the mean age at 15.95 years (SD = 1.86). The mean time to fracture healing was 25.71 weeks ± 7.88. Limb shortening in operated limbs of those with no previous surgery was (0.44 ± 0.86 cm) while those who had plate and screw fixation before surgery was 2 cm ($p = 0.027$). It could be observed that of all the variables studied only the patients who had a previous surgery (plate and screw fixation) were noticed to have poor squat and smile outcome compared to those who had no previous surgery. **Conclu-**

sion: Previous surgery on the limb with plate and screws resulted in more cases of limb length discrepancy and poorer lower limb function as assessed with the squat and smile score.

Keywords

SIGN Intramedullary Nailing, Tibia, Femur Fracture, Limb Shortening, Squat and Smile

1. Introduction

Paediatric femoral and tibial shaft fractures constitute 2% and 15% of all long bone fractures in children [1] [2]. Elastic stable intramedullary nails (ESINs) are often used for these fractures but the potential for complications is greater in older and heavier children [3]. Rigid nailing is a treatment option for children aged 11 years to skeletal maturity with diaphyseal femoral and tibia fractures [4] [5]. A common complication of nailing is limb shortening due to growth plate injury and growth arrest [6]. The squat and smile sign assesses functional outcome of the fractures. The "smile" component of the squat and smile protocol was omitted in the modifies scoring system due to subjectiveness and unreliability [7]. This study aims to assess long term treatment outcomes in children older than 10 years treated with rigid Surgical Implant Generation Nail (SIGN) intra-medullary nail, and the factors which can influence the treatment outcomes.

2. Material and Methods

This is a retrospective study. It is a series of 21 consecutive patients aged between 12 to 18 years who had fractures of the shaft of the femur or tibia treated with Surgical implant Generation network (SIGN) intramedullary nail over a 48-month period (between January 2013 and December 2017). The surgical approach was via small incision over the greater trochanter, entry point was 2 cm below the tip of the greater trochanter, hand reaming was done after open reduction through a small incision over the fracture site. The marrow was reamed 2 mm above the measured diameter of the canal and proximal and distal locking was done with the aid of external jigs. Image intensifier was not used. Partial weight bearing was commenced in the immediate post operative period and patient was seen every 4 weeks with x-ray check in clinic. Full weight bearing was commenced when fracture healing was noted on x-ray check.

Patients with bilateral fractures, infected non-unions and pathological fractures were excluded from the study. Data was collected from the SIGN Surgeons online database, patient case notes and radiographs. Patients were followed up for a period of 2 to 4 years. limb length discrepancy and squat and smile sign scoring were the outcome measures. Limb length discrepancy was measured by the direct method. A tape was used to measure the length between the antero-superior iliac

spine and the medial malleolus of the operated limb. This was done by two doctors, and the mean measurement was recorded and the difference with limb length of the unoperated limb was noted as the discrepancy. We did not record any cases of overgrowth. The squat and smile score was also assessed by 2 independent observers for degree of Hip and knee flexion up to 90 degrees and the need for assistive device. Inter-observer reliability was checked using the kappa statistic. Patient's variables such as age, sex, weight, mechanism of injury, side of injury (right/left), history of previous surgery, associated injuries, time to surgery, co-morbidities were analysed. Injury and implant related variables measured include fracture type, AO classification, presence of displacement, time to union, implant size and post-operative complications. Frequencies are expressed in actual numbers, means, standard deviations and percentages. Despite the small sample size, the students t-test and ANOVA were used for comparison of continuous and or categorical variables as indicated because mainly 2 groups were involved, and the normality of the data were confirmed visually with histograms.

Statistical analysis was performed using the SPSS statistical software. Statistical significance was set at $p< 0.05$.

3. Results

There were 8 males (38.1%) and 13 females (61.9%). The age range was 12 to 18 years with the mean age at 15.95 years (SD 1.86). The age distribution is as in Table 1.

Table 1. Age of patients.

Age (Years)	Frequency	%
12	1	4.8%
13	1	4.8%
14	3	14.3%
15	4	19.0%
16	2	9.5%
17	4	19.0%
18	6	28.6%
Total	21	100%

16 fractures (76.2%) were in the femur while 5 (23.8%) were tibia.

The weight of the patients ranged from 32 kg to 60 kg with a mean weight of 44.95 kg (SD 7.81 kg). The mean time to surgery was 170.71 days ± 430.14 with the lowest being 2 days and 1970 days being the longest time to surgery.

Outcome of the Surgery

The mean time to fracture healing was 25.71 weeks ± 7.88. The lowest being 14

weeks and the longest was 40 weeks. There was no incidence of avascular necrosis of the femur. The frequencies and percentages of the various measured variables is shown in Table 2.

There was no significant difference in limb shortening among the different weights (p = 0.733), the various times to surgery (p = 0.394), Time to fracture healing (p = 0.990), nail length (0.364) and nail width (0.258).

The influence of all other variables on the operated limb shortening was measured and patients who had a previous surgery with plate and screws and those who had co-morbidity (Obesity) demonstrated a significant level of limb length discrepancy as shown in Table 3.

Table 2. Variables measured.

Variable	Category	Frequency	%	p Value
Fracture side	Right	13	16.19%	0.275
	Left	8	31.8%	
Fracture type	Closed	19	90.5%	0.016
	Open	2	9.5%	
Mechanism of injury	RTA	18	85.7%	0.000
	Fall	3	14.3%	
AO Classification	A0	0	0.00%	0.000
	A1	13	61.9%	
	A2	8	38.1%	
Previous Surgery	Nil	18	85.7%	0.001
	Plate and Screws	3	14.3%	
Stability	Stable	6	28.6%	0.050
	Unstable	15	71.4%	
Co-Morbidities	Present	19	90.5%	0.000
	Nil	2	9.5%	

The ability to squat can assess the mobility and stability of joints and thus the quality of squatting is a proxy reflection of the functional outcome after fixation of lower limb fracture. The Squat & Smile test is reliable to predict the healing of lower limb fracture fixed with an intramedullary nail [7] due to lack of reliability the smile was not used in the grading. This is aptly illustrated in Table 4.

It could be observed from Table 5 that of all the variables studied only the patients who had a previous surgery (plate and screw fixation) were noticed to have poor squat and smile outcome compared to those who had no previous surgery, and the difference was significant.

The time to fracture healing did not show any significant statistical difference when compared to the squat and smile outcome scores. The age of the patients as well as the weights of the patients had insignificant statistical differences with p values of 0.547 and 0.947 respectively.

Table 3. Influence of variables on limb shortening.

Variable	Limb shortening (cm)		p-value
Sex	Male (1.00 ± 1.51)	Female (0.46 ± 0.88)	0.311
Bone	Femur (0.63 ± 0.96 cm)	Tibia (0.80 ± 1.79 cm)	0.776
Fracture Side	Right (0.77 ± 1.30 cm)	Left (0.50 ± 0.93)	0.616
Time to surgery	≥14 weeks (0.88 ± 1.26 cm)	<14 (0.00 cm)	0.143
complications	Nil (0.56 ± 1.15 cm)	SSI (2.00 ± 0.00)	0.100
Fracture type	Closed (0.74 ± 1.19)	Open (0.00)	0.405
Previous Surgery	Nil (0.44 ± 0.86 cm)	Plate (2 ± 2 cm)	0.027
AO Classification	A2 (0077 ± 1.01)	A3 (0.50 ± 1.41)	0.616
Associated Injuries	Nil (0.56 ± 1.15)	LL (1.33 ± 1.15)	0.292
stability	Stable (0.67 ± 0.98)	Unstable (0.67 ± 1.63)	1.000
Co-morbidity	Nil (0.42 ± 0.84)	Present (3.00 ± 1.41)	0.001

Table 4. Squat and smile scoring.

Knee Flexion/Squat break	Assistive device used	Score
Squat didn't break 90˚ at knee	Yes or no	0
Squat break 90˚ at knee	Yes	1
Squat break 90˚ at knee	No	2

Table 5. Influence of variables on Squat and Smile (S&S) score.

Variable	Category	S & S 1	S & S 2	p-value
Sex	Male	1 (12.5%)	7 (87.5%)	
	Female	1 (7.7%)	12 (92.3 %)	0.716
Bone	Femur	1 (6.3%)	15 (93.8%)	
	Tibia	1 (20.0%)	4 (80.0%)	0.361
Fracture Type	Open	0 (0.00%)	2 (100.0%)	
	Closed	3 (15.18%)	16 (64.2%)	0.544
Mechanism of Injury	RTA	3 (15.0%)	12 (85.0%)	
	Fall	0 (0.00%)	1 (100%)	0.676
Previous Surgery	Nil	0 (0.0%)	18(100%)	
	Plate and screws	3 (100%)	0 (0.00%)	0.000
AO Classification	A2	1 (7.7%)	12 (92.3%)	
	A3	2 (25%)	4 (75%)	0.271
Associated Injury	Nil	3 (16.7%)	15 (83.3%)	
	Lower limb fracture	0 (0.00%)	3 (100%)	0.445
Displacement	Displaced	1 (6.7%)	14 (93.3	
	Undisplaced	2 (33.3%)	4 (66.7%)	0.115
Co-morbidity	Nil	2 (10.5%)	17 (89.5%)	
	Present	1 (50%)	1(50%)	0.129

4. Discussion

The use of Elastic stable intramedullary nail is an option of treatment of long bone shaft fractures in older children, however a higher rate of unplanned surgeries and malunions have been observed in length unstable fractures and heavy (>50 kg) children and complications include excessive shortening which leads to nail protrusion and limb length discrepancy. The most common complication is pain or skin irritation at the nail insertion site caused by a prominent nail end [8] [9]. Current literature suggests that rigid intramedullary nail with a trochanteric entry point is the preferred mode of fixation of shaft femur fractures in adolescents [10]. Plate and screw fixation is also an option in older children, but the disadvantages are the difficulty in implant removal due to cold welding of locking screws to the plate, significant blood loss and relatively higher learning curve [11].

When the influence of these variables sex, bone involved, fracture side, time to surgery, complications, fracture type, previous surgery, AO classification, associated Injuries, and stability on the limb length shortening was checked there was no statistically significant difference in the categories except for the patients that had previous surgery which in this case was plate and screw fixation with dynamic compression plates. Those that had no previous surgery had a mean shortening on the operated limb of (0.44 cm ± 0.86) while the patients that had prior plate and screw fixation had a shortening of the operated limb of (2 cm ± 2) ($p < 0.027$). This was at variance with Del Balso *et al.* who recorded no cases of Limb length discrepancies in a study of 65 traumatic paediatric diaphyseal femur fractures in 145 patients treated with rigid IM nail fixation [12]. However, Eidelman *et al.* in a review of 11 patients treated aged between 8 to 16 years reported a patient with a limb length discrepancy of 2 cm [13] while Hammad *et al.* reported a 2.3 cm increase in femoral length and 2 cm increase in Tibia length in 6 patients with femoral fractures and 4 patients with tibia fractures treated with plating of a total of 15 patients [14].

Current literature suggests that rigid intramedullary nail with a trochanteric entry point is the preferred mode of fixation of shaft femur fractures in adolescents. However, growth disturbance due to physeal plate damage is still a concern with these nails and hence it is not preferred for use in children less than 12 years [15].

Two patients had co-morbidity (obesity) with a limb shortening in the operated limb compared to non-obese patients and had significant shortening 3.0 mm compared to 0.42 mm shortening for non-obese patients. ($p < 0.001$). There are no specific studies associating obesity with limb shortening after surgery in older children but retrospective studies of children with operatively treated femur fractures suggest that obese patients may be at increased risk for complications, including re-fracture, loss of reduction, wound infection, compartment syndrome, and malunion [16] [17].

The ability to squat can assess the mobility and stability of joints and thus the

quality of squatting is a proxy reflection of the functional outcome after fixation of lower limb fracture [7]. The influence of the following variables, age, sex, side. fracture type, mechanism of previous surgery, bone involved, AO classification, associated injuries fracture stability and co-morbidity on the quality of squatting based on the grading in table (squatting) was assessed and no significant differences were found except for those that had previous surgery with dynamic compression plate and screws. 18 patients had a mean squat and smile score of 2 while the 3 patients who had previous surgery with plate and screw fixation had a mean score of 1 ($p < 0.000$). There are not many studies on the factors affecting squat and smile in children after rigid intramedullary nailing of lower extremity long bones. Kroger *et al.* reported that some residual deficits in lower extremity movement biomechanics were identified at six months post-surgery in children treated with TENS nailing. Knee kinematics in squatting as well as knee kinematics during walking only recovered incompletely [18]. Some studies have suggested that there is reduction in strength of quadriceps by up to 25% at 18months and 3 years after intramedullary nailing in children [19] [20]. The cases with reduced squat and smile scores who had previous plate and screw fixation and were treated for non-union. The rate of non-union or delayed union in children older than 12 years is like that of adults [21] [22]. The fractures that ended in non-union were mainly due to high energy injury [23] or a consequence of added inappropriate fracture fixation [24] resulting further injury to the quadriceps mechanism and difficulty in squatting even after treatment with rigid IM Nailing.

Limitations of the Study

The numbers in this preliminary report are inadequate to draw far reaching conclusions. There is a need to conduct more studies on a larger number of patients to rule out the possibility of cofounding variables like previous surgeries on the fractures as there is little or no information on the surgical techniques used and post operative complications that may have arisen.

5. Conclusion

This study revealed that outcomes of treatment for long bone mid-shaft fractures of the lower extremities is good. Previous surgery on the limb with plate and screws resulted in more cases of limb length discrepancy and poorer lower limb function as assessed with the squat and smile score.

Authors' Contributions

All the authors were involved in conceptualization, Methodology, Formal analysis, Writing of the original draft, review & editing.

Conflicts of Interest

The authors declare no conflicts of interest.

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