THE UNIVERSITY OF NAIROBI

OCCURRENCE AND FACTORS PREDISPOSING TO LOWER LIMB LENGTH DISCREPANCY FOLLOWING TREATMENT OF PAEDIATRIC FEMORAL SHAFT FRACTURES WITH EARLY SPICA CAST AT THE KENYATTA NATIONAL HOSPITAL

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A dissertation submitted in part fulfilment for the award of master of medicine in orthopaedic Surgery of the University of Nairobi.

DECLARATION

I hereby declare that this study is my original work and has not been presented for a degree at any other university. All works used from other authors have been accordingly referenced.

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DEDICATION

I dedicate this dissertation to my wife Rachel and daughter Ruby for their love, support and patience.

I would also like to acknowledge my parents for their love and support. My Mom, Rose, who is in the medical field and has always been a great source for advice, encouragement and loving care. I would like to thank my Dad, Joseph, for his patience, unending support in my ever-changing life path, his never ending bank transfers to ensure I got an education, and his guidance in life. I am truly blessed to have you both as my parents.

ACKNOWLEDGMENT

I would like to express my immense gratitude to my supervisor's Dr Kirsteen Ondiko Awori and Dr Museve George Khateih for their steadfast support and guidance. Without their invaluable support, this work would not have been completed.

I would also like to give gratitude to the University of Nairobi department of orthopaedic surgery and Kenyatta National Hospital ethical and research committee for allowing me to carry out this research.

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ACRONYMS AND ABBREVIATIONS

ED: Emergency Department

KNH-UoN ERC: Kenyatta National Hospital-University of Nairobi Ethics and Research Committee

KNH: Kenyatta National Hospital.

LLLD: Lower Limb Length Discrepancy

UoN: University of Nairobi

A&E: Accident and Emergency

ASIS: Anterior Superior Iliac Spine

BMI: Body Mass Index

ESINs: Elastic Stable Intramedullary Nailing System

AO/OTA: AO-Muller/Orthopaedic Trauma Association

ORIF: Open Reduction and Internal Fixation

KMTC: Kenya Medical Training College

GT: Greater Trochanter

ABSTRACT

Background: No local studies have examined the prevalence and factors predisposing to lower limb length discrepancy following treatment of paediatric femoral shaft fractures with early spica cast. The present study was carried out at the Kenyatta National Hospital to fill this gap.

Methodology: This was a cross-sectional analytical study design that enrolled 35 paediatric patients (aged 3 months to 5 years). The participants were recruited through consecutive sampling. The independent variables were the patient's body mass index and fracture pattern as classified under AO-Muller/Orthopaedic Trauma Association (AO/OTA) system. The intermediate variable was the spica cast application method. The dependent variable was lower limb length discrepancy. The patients were recruited into the study at the time of spica cast removal. Their weight and height was measured, and their body mass index (BMI) was calculated. The fracture type was classified according to AO/OTA classification using the injury radiograph from the patient's file. Clinical limb length was measured for each limb and compared.

Data analysis: Descriptive were presented using charts, tables, and graphs. Pearson chi-square was used to examine the relationship between BMI and LLLD, while spearman's correlation was used for examining that between AO/OTA fracture type and LLLD.

Results: There was a 100% response rate. The ages ranged from 24 months to 42 months with an average of 34.8 months. More females (54%) than males (46%) affected. The average BMI was 14.1, and none of the patients were noted to be obese when matched to BMI-for-age percentile. Majority (57.2%) were found to be in the underweight category. The most common AO/OTA classification fracture types were 3, 2, A2 at 37.1% (n=13); followed by 3, 2, A3 at 22.9% (n=8); 3, 2, A1 at 17.1% (n=6); and 3, 2, B2 at 11.4% (n=4). LLLD was present in 48.6% (n=17) of the cases, with only one participant having clinically significant shortening (2 centimetres). There was no statistically significant association between the BMI in percentiles and the LLLD (Chi-square value 13.673, D.F-26, P-value 0.997). There was no relationship between BMI and presence or absence of LLLD (OR-1.38: Value 0.208). There was no statistically significant correlation between the fracture type classification and lower limb length discrepancy (Spearman's rho -0.173, P-value 0.32).

Conclusion: Treatment of paediatric fractures of the femur with spica casting at KNH is generally satisfactory with respect to lower limb length discrepancy.

1.0. INTRODUCTION

1.1. Background

Femoral shaft fractures are common in paediatric orthopaedic trauma and often require hospitalization. Beaty et al. (1) found femoral fractures to be the third most common lower limb paediatric fractures in North America affecting 1.6 % of children. Femoral fractures account for approximately 10 % of all paediatric admissions at the Kenyatta National Hospital orthopaedic unit (2).

Management of femoral fractures in children varies and is influenced by the mechanism of injury, age of patient, weight, the fracture pattern, family circumstances, and the cost of treatment methods available (3). According to Khoriati et al. (4), the treatment of femoral fractures in the paediatric femur largely depends on the chronological age of the child, bone age and the child's size. The treating surgeons' experience, the cost and accessibility of alternative treatments may also influence the management of these fractures. In the developing world, especially and specifically in KNH, the use of non-operative management for femoral fractures is still undertaken in some situations. This is despite a current trend towards operative fixation being preferred for appropriately selected paediatric patients as it allows early mobilization and shorter hospital stays (4). The paediatric skeleton has unique features such as open growth plates, thicker periosteum, and different biomechanical behaviour in response to loading. These features play a role in determining which treatment methods can be used for fractures. Operative challenges unique to children include injury to the physes, need for follow up surgery for early removal of the implant due to continued growth of bones, and paediatric patients who are uncompliant to strict post-surgery protocols leading to implant failure. The general risks of operative fixation that include bleeding, infection, and anaesthetic complications as relates to surgery in adults still apply (4).

The paediatric femur has a high potential for remodelling and can bear up to 25 degrees of angulation in any plane. While rotational deformity is less tolerated, as much as 25 % of malrotation is still acceptable (4). For children under the age of ten years, local injury results in stimulation of the vessel-rich periosteum resulting in bone overgrowth, hence, a shortening of up to 1 centimetre is acceptable. These unique characteristics of the paediatric long bones are what makes the conservative treatment of paediatric fractures a widely accepted mode (4).

1.2. Statement of the problem

Femoral fractures are common in Kenya due to challenges that are prevalent in developing nations that cause a high burden of trauma. These include poor road safety infrastructure, underdeveloped building safety construction policies, and inadequate public health safety laws leading to high injury rates. This leads to trauma case overload in hospitals, thus, affecting negatively the penetration of surgical care to all who need it.

This problem is further worsened by the low socio-economic status of the majority of the populace. Kenyatta National Hospital, which is the main government-owned referral centre in Nairobi city, is surrounded by several urban slums leading to an influx of injured patients who cannot afford modern operative treatment options for injuries such as paediatric femoral shaft fractures. This leads to a vast majority of the injured paediatric patients having to receive non-operative care options for injuries that could otherwise benefit from operative fixation. Spica casting is one of the most widely used conservative modes of treatment for femoral shaft fractures in children aged three months to five years at the KNH.

The above issues coupled to developing nation challenges such as increasing populace living under 1 dollar per day and increasing national debt putting strain on service provision, means that there is no right to improved healthcare above the current state. Therefore, conservative methods of treatment are here to stay.

1.3. Study Question

What is the occurrence and factors predisposing to lower limb length discrepancy following treatment of paediatric femoral shaft fractures with early spica cast at the Kenyatta National Hospital?

1.4. Objectives of the study

1.4.1. Broad

To determine the occurrence and factors predisposing to lower limb length discrepancy following treatment of paediatric femoral shaft fractures with early spica cast at the Kenyatta National Hospital.

1.4.2. Specific

1. To determine the body mass index (BMI) distribution among paediatric patients treated with spica casting for femoral shaft fractures at KNH.
2. To determine the common femoral shaft fracture patterns based on AO/OTA classification for paediatric patients treated with spica casting at KNH.

3. To determine the rate of limb length discrepancy after removal of the spica cast treatment.
4. To examine the relationship between BMI of the patient and limb length discrepancy at spica cast removal.
5. To examine the relationship between fracture classification type (AO/OTA) and limb length discrepancy at spica cast removal.

1.4. Study justification and significance

A spica cast, when correctly applied, has been shown to have excellent outcomes with few complications. Despite its immense usefulness in paediatric femoral fractures, it is not without complications. The most notable ones being lower limb length discrepancy, skin breakdown under the cast, and loss of fracture reduction leading to issues such as unacceptable malrotation. There is a paucity of studies locally that have looked at the LLLD complication rate after spica cast treatment, and possible predisposing factors for its development.

It is hoped that the findings of this study can be used to establish which group of paediatric patients can be treated safely with a spica cast. This information can be used to develop paediatric clinical guidelines by recommending which femoral fractures can be safely managed using spica cast and, thus, improve the care given to paediatric femoral fracture patients.

1.5. Conceptual framework

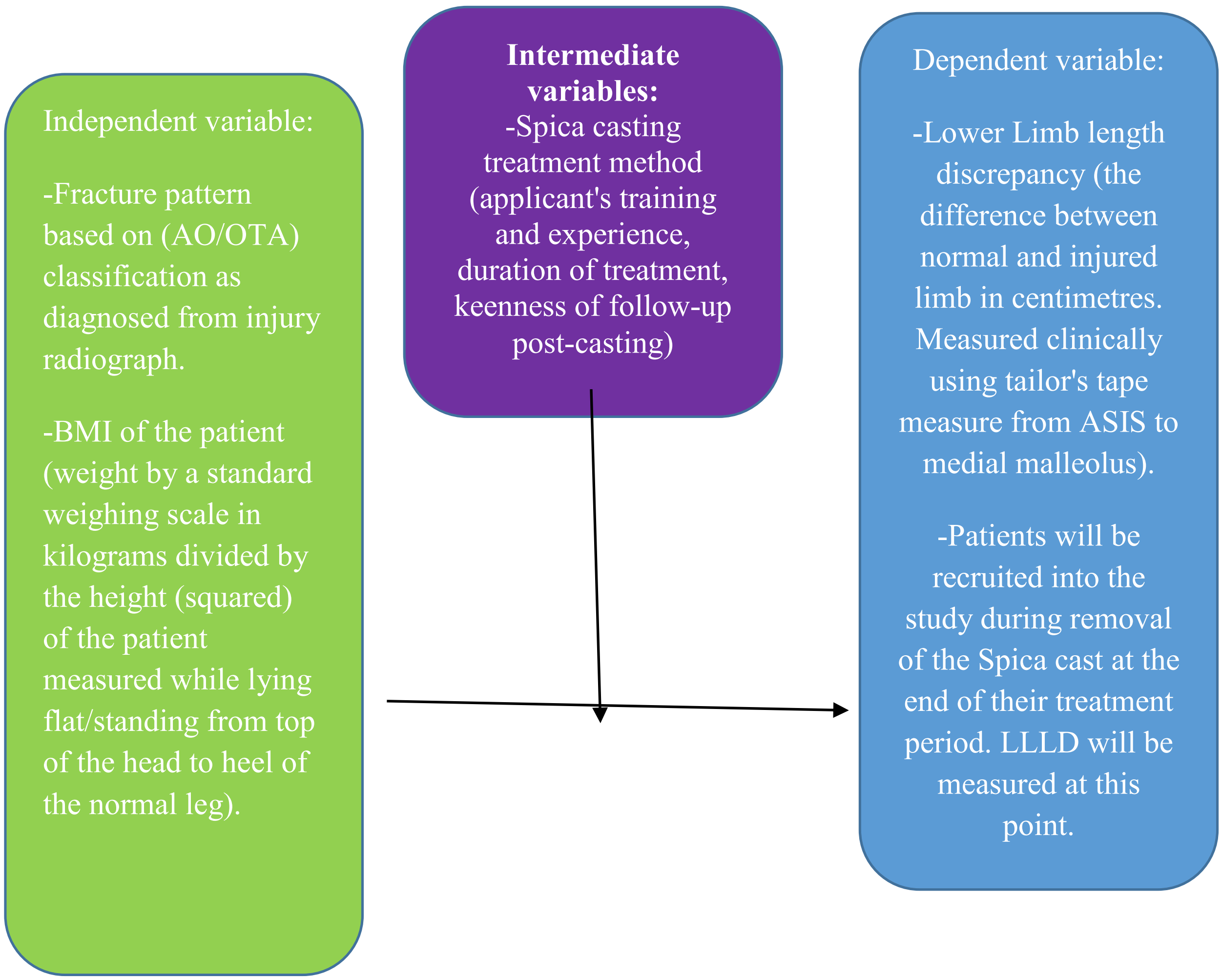


Figure 1: The conceptual framework model for predisposing factors to developing lower limb length discrepancy after treatment with early hip Spica casting

2.0. LITERATURE REVIEW

Conservative treatment of paediatric femoral fractures requires keen attention to detail and close follow up in order to reduce the risks of complications. Lower limb length discrepancy and loss of reduction leading to malrotations are common complications of this treatment. Careful patient selection and good follow up are required in order to correct any arising loss of reduction during the healing process. This will prevent lifelong morbidity due to incorrectly healed paediatric femoral shaft fractures which include increased risk of lower limb joint(s) osteoarthritis, ankle contractures, and spine disease (4).

2.2. Overview of the treatment of paediatric femoral fractures

Femoral fractures are caused when a considerable amount of external energy impacts the bone. The force resulting to the fracture influences the type of fracture. This can be spiral/oblique fracture type which occurs due to rotational forces, transverse fractures occurring due to direct bending forces, and comminuted due to crushing or high energy forces (5).

The displacement of fragments after a fracture is mainly determined by the muscular attachments. The residual fragments displacements have a role to play in the non-satisfactory outcomes of conservative management of paediatric femoral fractures. The attachments of the gastrocnemius muscle pulls the lower third femoral fractures posteriorly. The middle third fracture displacement is largely determined by the nature of the force causing the fracture, and the overlap by the pull of the adductor group of muscles.

In proximal third fractures, the proximal fragment is normally flexed, externally rotated, and in abduction due to various muscle groups (6).

The choice of definitive treatment of paediatric femoral fractures is usually affected by a number of factors. These include the age of the child, surgeons' experience, soft tissue status and skin cover over the fracture, location and degree of fracture segment displacement, associated injuries, and social situation (7). According to D'Ollonne et al. (8), the gold standard for the treatment of children under eight years is the non-operative method due to excellent bone union and remodelling qualities. However, lower limb length discrepancy which results from fracture site mal-reduction is the main complication of this method.

Skeletal traction until fracture becomes clinically "sticky" followed by spica cast immobilization for three to twelve weeks has been the proposed method of treating paediatric femoral shaft fractures which are at risk of poor outcome if treated with early spica casting (9). The drawback with this method is prolonged hospitalization and immobilization. However, a shift towards surgical fixation for appropriate fractures has been advocated in the recent past due to shorter immobilization time, shorter hospital stay, and faster rehabilitation (10). The development of new implants such as flexible intramedullary nails has favoured this shift. Surgical fixation has disadvantages of potential physeal injury, infection, necrosis, and implant failure. There are those who still favour the use of conservative methods but advocate for early spica casting without traction, due to fewer complications and shorter hospital stay and, thus, earlier return to function (11).

For neonates and infants less than three months old, the Pavlik harness method has been preferred. From three months to five years, the commonly used method is the spica casting. For older children, flexible intramedullary nailing is the most commonly used in the developed nations to treat femoral fractures in children aged between six to twelve years. From twelve years until skeletal maturity, lateral trochanteric nailing is considered a safe option. Submuscular plate stabilization is also considered a safe and effective method of treatment of unstable fractures involving all ages from toddlers to skeletal maturity. Monolateral external fixators can be used to treat patients with polytrauma, and those with severe open fractures although it has been linked with high rates of re-fractures (12).

2.2.1. Spica casting as a treatment mode

This is one of the most accepted methods to conservatively treat femoral shaft fractures in children aged between three months and five years since its description by Moore and Schafer in 1948 (13). Studies have found early spica casting to have an overall excellent outcome. Ferguson and Nicol (14), examined the outcomes of 101 femoral shaft fractures in children under the age of ten years treated by early spica casting. They found a very small number of complications with only four spica casts having had to be removed due to unacceptable shortening. Monthir and Hameed (15) conducted a prospective study on the outcomes of both early and delayed spica casting in 28 children aged eight years or younger. Their results showed excellent outcomes with complication rates of less than 16.5 % (15).

The standard method of application of spica casting according to Wheeless Online Textbook of Orthopaedics (16) is described in appendix D.

2.2.2. Lower Limb Length Discrepancy complication

Limb length discrepancy is one of the most common complications of conservative treatment of paediatric femoral fractures. It is described as length asymmetry between the right and left lower limb (anisomelia). It is a fairly common finding in healthy paediatric and adult populations. A survey of 376 paediatric patients conducted in Boston, Massachusetts found that 95.5 % of those tested have limb length discrepancies (17).

Although LLLD might not cause problems to all who have it, it has been reported that an LLLD surpassing 2 centimetres leads to significant gait asymmetry. In practical terms, such asymmetries mean that the longer leg bears more weight for a longer time, with cumulative effects that may include increased risk of hip or knee osteoarthritis, increased energy expenditure during the gait cycle, plantigrade ankle contracture, and disruption of pelvic symmetry leading to spine disease (18).

Chances of acquired limb length discrepancy developing due to fracture can be avoided during hip spica application. The surgeon needs to understand the acceptable reduction parametres based on age during its application and at removal. It is advised (19) to achieve less than 1 centimetre shortening at the time of cast application, and close follow-up during the initial 2 weeks following application so as to achieve an acceptable outcome.

Table 1: Acceptability criteria for closed reduction of fracture shaft of femur based on age

Age (years)	Shortening (millimetres)	Angulation anterior-posterior (degrees)	Angulation varus/valgus (degrees)
Birth to 2 years	15	30	30
2-5 years	20	20	15
6-10 years	15	15	10
11 to maturity	10	10	5

Source (20): *James BH, James KR. Rockwood & Wilkins' Fractures in Children. 6th edition. Lippincott Williams & Wilkins. 2006:901.*

Apart from shortening, LLLD can occur due to overgrowth of the affected limb. It is usually noted in cases where the reduction of the fracture edges is exact, and especially in the ages between two and ten years. This has been attributed to an increase in linear growth secondary to post-traumatic increase in local blood flow. This is most significant within the first 15 months after injury and is independent of the type or level of the fracture. The overgrowth is usually between 1 and 1.5 centimetres. This phenomenon is not seen in children under two years due to the rapid rate of healing (3 weeks) and fracture consolidation. This prevents overgrowth. Children older than ten years have a reduced rate of healing and do not respond to the stimulation, hence, no overgrowth (21).

LLLD can be measured clinically or radiographically. Radiological methods are the most accurate and widely preferred when discrepancy correction is being planned. Radiological methods of LLLD assessment include; Teleoroentgenography, orthoreonthography, scenography, and computed tomography (CT) (22). Clinical methods of LLLD assessment can either give true or apparent measurements of the limb. Apparent limb length is measured from the umbilicus to the medial malleoli of the ankle of the desired limb using a tape measure. This method is especially useful when lengths of the appendicular skeleton may be equal, but apparent shortening may result from pelvic obliquity or contractures around the hip and knee joints (23). True limb length measurement is obtained by using a tape measure to get the distance between the anterior superior iliac spine (ASIS) and the medial malleolus of the desired limb. However, differences in the circumference of the two limbs, and difficulty in identifying the bony landmarks, as well as deformities related to limb angulation can lead to errors using this clinical measurement tool. Moreover, fibular hemimelia and posttraumatic bone loss of the foot are causes of LLLD resulting in limb shortening occurring distal to the ankle mortise (23). The clinical method of measuring LLLD is non-invasive, safe, affordable and easy to use but is less accurate when compared to the radiological methods such as a scanogram. It has been found that by averaging the distance between the medial malleolus and the ASIS, the clinical method has acceptable reliability and validity with an estimated error of +/- 8.6 millimetres (24).

2.3. Relationship among Age, Body Mass Index and LLLD

The initial peak age of paediatric femoral fractures is from one to three years, and normally due to low energy followed by a second peak at adolescence due to high energy (25). Mutiso et al. (26) in a study on the distribution of paediatric fractures at KNH in 2016 revealed that most lower limb fractures occurred between the ages of two and six years. Mehmood and Shah (27), in a study of 107 femoral fractures treated by spica casting found

LLLD of shortening as one complication of hip spica casting. It occurred in 14 % of the patients, and it was associated with the older age group of five to six years.

According to Buehler et al. (28), a successful outcome can be achieved with early spica casting in children aged two to ten years with uncomplicated shaft fractures of the femur and a negative telescope test. They analysed 47 children with uncomplicated femoral shaft fractures aged sixteen months to six years treated with hip spica cast, to ascertain if early spica cast treatment resulted in an unacceptable outcome. In their study, unacceptable outcome was defined as greater than 25 millimetres of fracture overlap at three to four weeks of follow up. They found a complication rate of 18 % with no relationship between the patient's age and treatment outcome. A telescope test involves examining patients by gentle axial compression under fluoroscopy where demonstration of more than 3 centimetres shortening is associated with a higher incidence of mal-union and unacceptable results.

Cassinelli et al. (29), studied 145 children aged less than seven years with femoral fractures to determine the relationship between age and complication rates following early spica cast treatment. They concluded that children younger than six years could be treated successfully with low complication rates including angulation, shortening, or emergency room return visits. Children under two years of age were noted not to have any complications, while those between two and five years had a low complication rate of 13.5 %. In the absence of child abuse or polytrauma necessitating hospital admission, a spica casting can be applied in the Accident and Emergency followed by immediate discharge (29). Harigah et al. (30) in a study comparing the use of Elastic Stable Intramedullary

Nailing system (ESIN) and spica casting in children aged nine months to ten years found no relationship between age and the final LLLD persisting to skeletal maturity (p=0.071).

Obesity presents a challenge to the fitting of spica casts. It is generally considered that large body contours and increased cast to bone distance in obese patients results to failure of treatment. Gilbert et al. (31) evaluated the role of obesity in fracture severity and choice of treatment. The patients numbered 337 and were aged two years to ten years. Obesity was defined as a weight for age >95th percentile. They concluded that obese children were more likely to need open reduction and internal fixation (ORIF) as compared to their non-obese counterparts. Neill et al. (32) to examine the influence of obesity on the operative and non-operative management of paediatric extremity fractures, and concluded that obese paediatric patients are significantly more likely to require ORIF than non-obese patients. Hendersen et al. (33) did a prospective study of 26 children under the age of ten years in 1984 to establish the outcomes of early spica casting in femoral shaft fractures. They concluded that factors like obesity can be a relative contraindication to this treatment technique. A systematic review was also carried out by Jain et al. (34) in 2014 to examine the controversies in orthopaedic trauma management of femoral shaft fractures in children between six and twelve years of age. One of their findings was that large/obese paediatric patients present a major challenge to successful spica casting treatment.

2.4. Relationship among fracture location, pattern, and LLLD

The specific fracture pattern and location has been showed to play a role in the treatment type chosen by surgeons and the outcome of the treatment. Understanding how these factors affect the application position of spica casts is essential for good outcomes in femoral fracture treatment. Mutiso et al. (26) described the paediatric fracture patterns seen at KNH. They found that of the paediatric long bone fractures, the femur was involved in 33 % of the cases. In terms of location of the distribution of the femoral fractures; diaphyseal / shaft fracture was 82 %, with distal metaphysis at 8%, distal epiphysis at 8%, and proximal metaphysis involved in 3%. Comminuted fractures represented 12 % with the lower limbs being mostly involved. The femur was involved in 5 % of the fractures, tibia in 4 %, and fibular in 2.5 %. Four of these were Salter-Harris I and 10 were Salter-Harris II fractures (26). Mid femoral shaft fractures are more likely to be involved in LLLD shortening complication compared to proximal shaft fractures (27). However, there are authors who have disputed that there exists a relationship among these variables. Buehler et al. (28) found that there was no relationship between fracture type and location to early spica cast treatment outcome. Harigah et al. (30) concluded in their study that there was no relationship between the level of fracture (p=0.132) and fracture type (p=0.926) to final LLLD.

Clinical guidelines from the American Academy of Orthopaedic Surgeons on the management of mid-shaft femoral fractures in the paediatric population advice delayed spica casting for unstable femoral shaft fractures. In this protocol, they advocate for early use of skin traction to reduce and align the fracture until union begins before a spica cast is applied. Unstable femoral fractures are those with severe displacement, comminution pattern, long spiral/oblique patterns, or initial fracture shortening of more than two to three centimetres. These should ideally be surgically managed (35).

2.5. Conclusion

There is no consensus on the factors predisposing to poor outcomes following treatment of paediatric femoral fractures with spica cast as evidenced by the literature reviewed. All studies reviewed agree on the fact that complications following treatment occur, especially if patient selection and follow up is not optimum. Other well-described complications following spica cast treatment include compartment syndrome, malrotation, skin breakdown with consequent infection, and superior mesenteric artery syndrome (rare). Despite these complications, most of the studies reviewed reported a satisfactory outcome (36-38).

3.0. PATIENTS AND METHODS

3.1. Study site and design

This cross-sectional study analysed the rate of lower limb length discrepancy and possible predisposing factors following treatment of paediatric femoral shaft fractures with early spica casting at the Kenyatta National Hospital. Data was collected from the orthopaedic plaster technician rooms in casualty and clinic during the removal of the spica cast at the end of the treatment period.

3.2. Study population

The study was conducted among 35 paediatric patients aged between 24 months and 42 months who had received a spica cast as primary treatment for isolated femoral shaft fractures.

3.3. Inclusion and exclusion criteria

All Paediatric patients five years of age and below with isolated femoral shaft fracture diagnosed by radiograph and treated using spica casting in KNH were recruited in a consecutive manner until the sample size was achieved. Only 2 patients were excluded due to lack of radiographs in their medical files. Patients were excluded if their guardians refused to consent, underwent other modes of treatment apart from early spica casting for their fracture, LLLD resulted from deformities outside the femoral shaft, existence of lower limb pathology manifesting with a history of gait abnormality was present, and lack of key data in their file such age or radiographs.

3.4. Sample size determination

A sample size of 35 patients was recruited into the study after calculation using the finite population method.

$n^1 = N*X / (X + N – 1)$

Where;

$X = Z_{\alpha/2}^2 *p*(1-p) / MOE^2$,

And $Z_{\alpha/2}$ is the critical value of the Normal distribution at α/2 (e.g. for a confidence level of 95%, α is 0.05 and the critical value is 1.96), MOE is the margin of error (4.74%), p is the sample proportion, and N is the population size. Note that a Finite Population Correction has been applied to the sample size formula.

n^1=sample size that is corrected for a finite population

N=size of the finite population = 45 (Data from the KNH A&E trauma plaster unit shows a total number of 45 patients treated for femoral fractures via hip spica casting between the months of May, June, and July 2020).

Z=Statistics for 95% confidence interval=1.96

P= expected proportion of femoral shaft fractures in paediatric patients (10% in KNH from the literature review, therefore P= 0.01)

α = precision at 5 % (therefore, α =0.05)

According to literature, the minimum sample size required for statistical significance for any analytical study is thirty patients (39).

3.6. Sampling technique

A consecutive sampling of all patients who met the inclusion criteria was done, until the sample size was achieved.

3.7. Ethical Consideration

This study was approved by the Kenyatta National Hospital-University of Nairobi Ethics Research Committee (KNH-UoN ERC) under protocol number P675/12/2020. Data collection only commenced after approval. A thorough explanation of the study and its objective was given to the possible participants. Written informed consent was obtained from all the participants. There was no coercion or bribery to participate in the study.

Any information obtained for the purpose of the study was treated with confidentiality. Participants were allocated codes that were used as a key to store their data on a password-protected database. No names were used. Only the principal researcher has access to the database. All hard copy information collected is stored under lock and key, in a cabinet that only the principal researcher can access.

3.8. Data collection

A structured interviewer-administered questionnaire was used (Appendix A).

The patients were selected with the help of two assistants who were clinical officers (holders of a diploma in clinical medicine and surgery from the Kenya Medical Training

College -KMTC). The assistants, Zachary and Hassan, were trained on data collection from a small number of patients during the pre-test. The principal researcher constructed a questionnaire designed to answer the research question, and also trained the research assistants on how to classify femoral shaft fractures according to AO/OTA system. The completeness and accuracy of the questionnaire was assessed by the study supervisors. A pre-test was conducted to test for reliability. Patients were managed according to hospital protocol with no interference from the research team. The study team left their contact details at the plaster of Paris rooms in the accident emergency department and orthopaedic clinic, and they were notified every time there was a patient having a hip spica cast removed for a healed femoral shaft fracture. The study team reviewed the patient's file, and determined if they met the inclusion criteria. If they did, consent was sought from parents/guardians. The notes within their files were reviewed according to the developed data collection questionnaire. The data was collected using a pre-tested questionnaire that noted the patient's biodata. The research assistant reviewed the initial injury radiograph, and classified the location and fracture pattern according to AO/OTA system. After removal of the early spica cast, the researcher then performed the following clinical examination process to determine the true clinical length of the limbs. The process helped identify any discrepancy, and ensured no confounding factors like fixed flexion deformities existed.

The patient was fully undressed leaving only underwear (in the older children) and positioned supine on a flat, firm examination couch. Both lower limbs were fully extended at the knee and hip joints while being held parallel to each other. The pelvis was then squared by palpating for the left and right anterior superior iliac spines (ASIS), positioning them at the same level to each other, and right angles to the long axis of the trunk and lower limbs.

The true length of the limb was then determined using the following process (using a tailor's tape measure):

1. The metal tip of the tape measure was placed immediately distal to the ASIS and held down firmly with the thumb on the bone.
2. The second bony landmark that was used to ascertain the limb length was the medial malleolus of each limb. The tip of the examiner's index finger was pressed against the bone immediately distal to the tip of the medial malleolus. The tape measure was then held taught between the same index finger and the thumb; the thumb nail indicated the point of measurement.

The length of each limb was determined in this manner. Each limb was measured three times and the average of the three measurements was taken as the final reading. This afforded intra-observer reliability. The second research assistant independently repeated the process. The two averages from the two researchers were then averaged to provide the final limb length, thus, affording inter-observer reliability. This minimized the error of margin for this direct LLLD assessment method. To calculate the LLLD, the length of the healed limb was subtracted from the normal one. The difference, if any, was expressed as positive or negative. A positive number indicated lengthening, while a negative one indicated shortening of the affected limb (Figure 2).

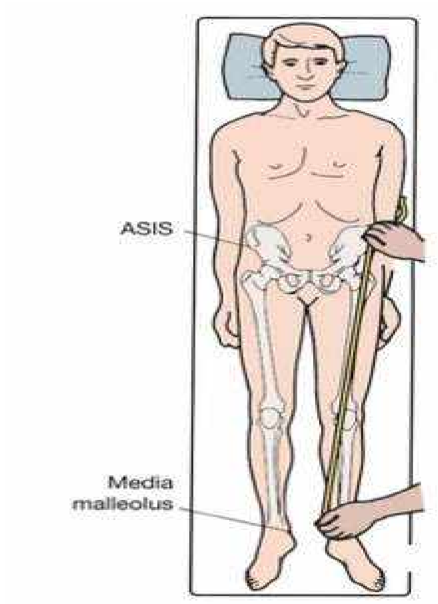


Figure 2: Showing the landmarks for limb length measurement

The BMI of the patient was calculated by dividing the patient's body weight in kilograms by their height in metres squared. The weight was obtained using a TRACK® Analog Salter Type baby weighing scale. The scale was analogue with a maximum capacity of 25 kilograms and was rated for use in paediatric ages up to five years old. It had a 100 gram precision interval and an error of +/- 0.01. It is widely used for anthropometric surveys and growth monitoring.

Height was obtained using two data collection tools depending on the child's age. Children two years and below were measured using an infantometre, while those older than two years were measured using a stadiometre. A Seca® 213 stadiometre which had a height measuring range of between 20 centimetres and 205 centimetres, a precision interval of 0.5

centimetres, and an error of +/- 0.001 was used. A Seca® 416 infantometre which had a length measuring range from 33 centimetres to 100 centimetres, a precision interval of 0.1 centimetres, and an error of +/- 0.001 was used.

$$BMI = \frac{\text{weight (kg)}}{\text{height (m}^2\text{)}}$$

3.9. Study Variables

Independent variables were the fracture pattern according to AO/OTA classification, and BMI of the patient. The intermediate variable was the spica cast treatment method. The dependent variable was lower limb length discrepancy.

3.10. Data Analysis and Management

The collected data was analysed for appropriateness. The completeness and accuracy of the questionnaire was assessed by the study supervisors. A pilot study was conducted to test for reliability. The questionnaire was pretested on 10% of the sample size during the pilot study. This enabled the principal researcher to evaluate whether the data collection tool was adequate or required modification before the actual data collection begun.

Data was then cleaned, coded, and exported for analysis using SPSS version 27. Descriptive statistics (age, BMI and fracture AO/OTA) type was presented in form of tables, graphs, and charts. Pearson chi-square was used to examine the relationship between BMI and LLLD, while spearman’s correlation was used for examining that between AO/OTA fracture type and LLLD.

3.11. Study Results Dissemination

The results were presented to the department of orthopaedic surgery faculty for review before dissemination to KNH-UoN ERC and the University of Nairobi research library. All results will be made available to the study subjects for review. The outcome of the study will eventually be submitted for journal publication. This will be done in tandem with the research assistants and dissertation supervisors. Both the Kenyatta National hospital and the UoN department of Orthopaedics will be recognized affiliate parties in the publication.

3.12. Limitations

One of the major limitations to the study was due to LLLD arising from pathologies outside the femur. This limitation was mitigated as follows:

1. Abnormalities arising proximal to the greater trochanter were ruled out by constructing the Nelaton's line (figure 3) for each lower limb. This was done by placing a rigid ruler between the tip of the ASIS and the ischial tuberosity and a line drawn on the anterior edge of the ruler. The greater trochanter (GT) was then palpated and its position relative to the line determined. In hips without abnormality, the GT is either distal or at the level of the line. Both hips were compared to exclude femoral shortening arising proximal to the GT.

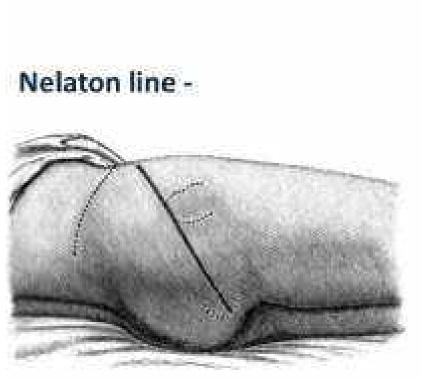


Figure 3: Nelaton’s line illustration.

2. Abnormalities arising from the tibia were ruled out by flexing the hip and knees of both limbs next to each other at 45 degrees and aligning the feet in a parallel manner (Figure 4). This is known as the galeazzi test. The level of the knee on the affected limb will be observed. The apex direction of the knee will determine if the shortening is due to tibia or femoral abnormality.

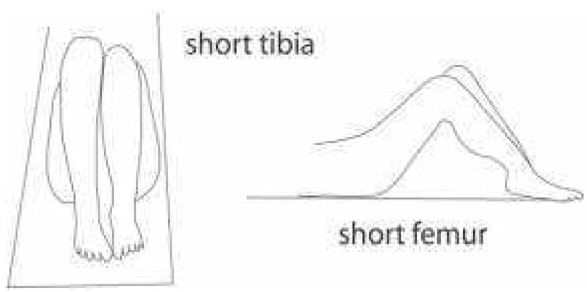


Figure 4: Assessing tibia abnormalities

3. Abnormalities of fixed hip flexion deformity were ruled out by performing the Thomas test. The first step of this test was done by having the patient lie supine on the examination table. The researcher then passed the palm of his hand beneath the patient's spine to identify lumbar lordosis. Secondly, he flexed the hip on the normal

side until the thigh just touches the abdomen to obliterate the lumbar lordosis. The pelvis should be in the neutral position (not tilted anteriorly or posteriorly). Finally, the clinician passively ranged the hip on the affected limb side into extension. If the entire pelvis began to tilt anteriorly causing a lordosis, he stopped the passive range of motion since this was a positive indicator for fixed flexion deformity. If the hip flexion deformity was severe (could not be compensated for despite increased lumbar lordosis), and prevented the limb from being measured while lying straight/ flat on the examination couch; the subject was excluded from the study.

Budgetary constraint was another limitation. This was mitigated by frugal spending guided only by the budget. Time constraint was another major limitation, and this was overcome by proper time management and adhering to the study timeline plan

3.13. Covid-19 Mitigation Measures

The primary researcher ensured that all members of his study team were trained on key aspects of COVID-19 infection prevention to mitigate the risk of infection. This included conducting online training for them with the help of the World Health Organization (WHO) portal (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/training/online-training) and providing them with personal protective equipment as per WHO guidelines of risk stratification.

4.0. RESULTS

This chapter gives the results of the study findings. These findings are presented based on the study objectives. The results are presented in sections that include: response rate, demographic information, BMI distribution, femoral shaft fracture patterns, rate of lower limb length discrepancy, relationship between BMI and LLLD and relationship between fracture classification and limb length discrepancy.

4.1. Response Rate

A total of 35 paediatric patients participated in the study giving a response rate of 100%.

4.2. Demographic information

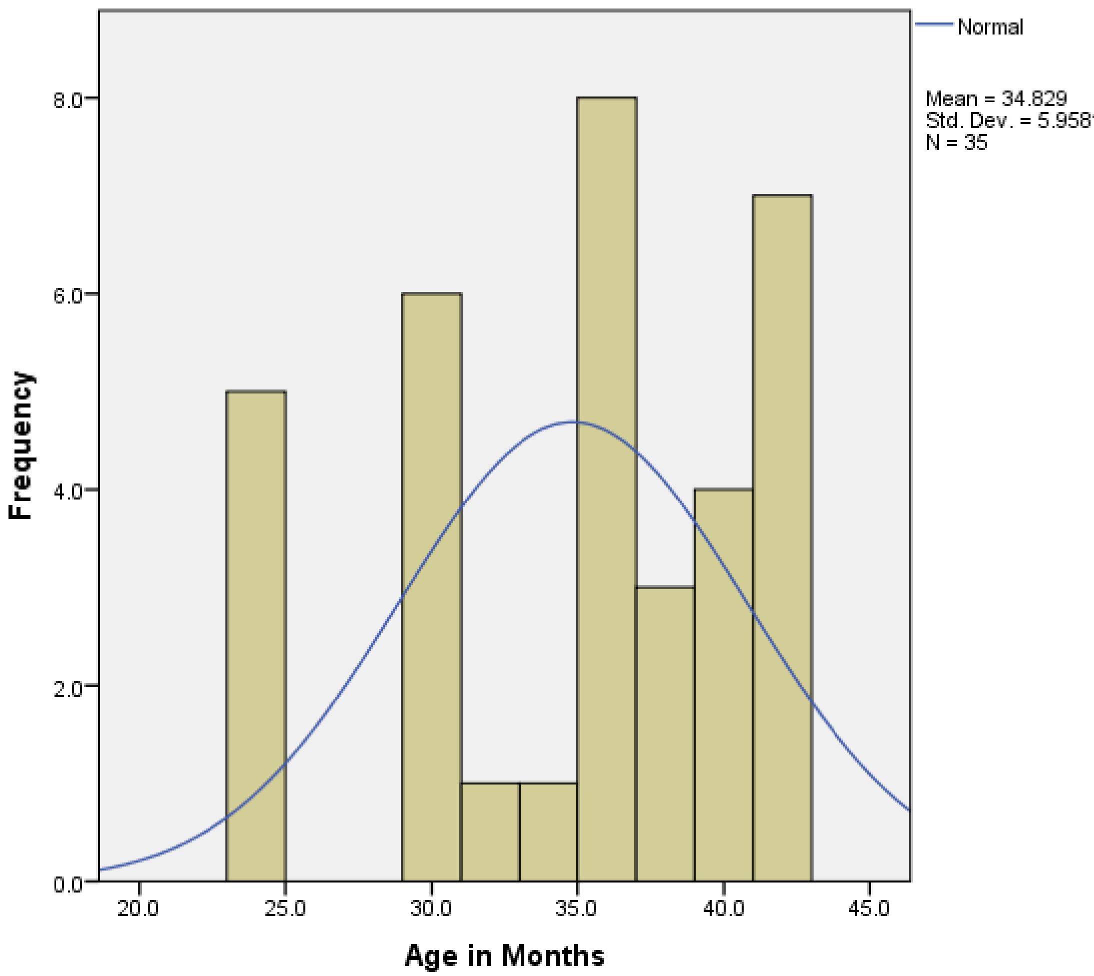
4.2.1. Age

The mean age for the children was approximately 35 months (95% CI; 32.87 to 36.79). The youngest was 24 months while the oldest was 42 months. Table 2 and figure 5 below show the age distribution among the children recruited in to the study.

Table 2: Age distribution

	N	**Minimum**	**Maximum**	**Mean**		**Std. Deviation**	**Variance**
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Age in Months	35	24	42	34.829	1.0071	5.9581	35.499

Figure 5: Histogram for age



4.2.2. Gender

The number of females who had femoral shaft fractures was 19 (54%), while males was 16 (46%). Figure 1 below shows the distribution of femoral shaft fractures as per gender.

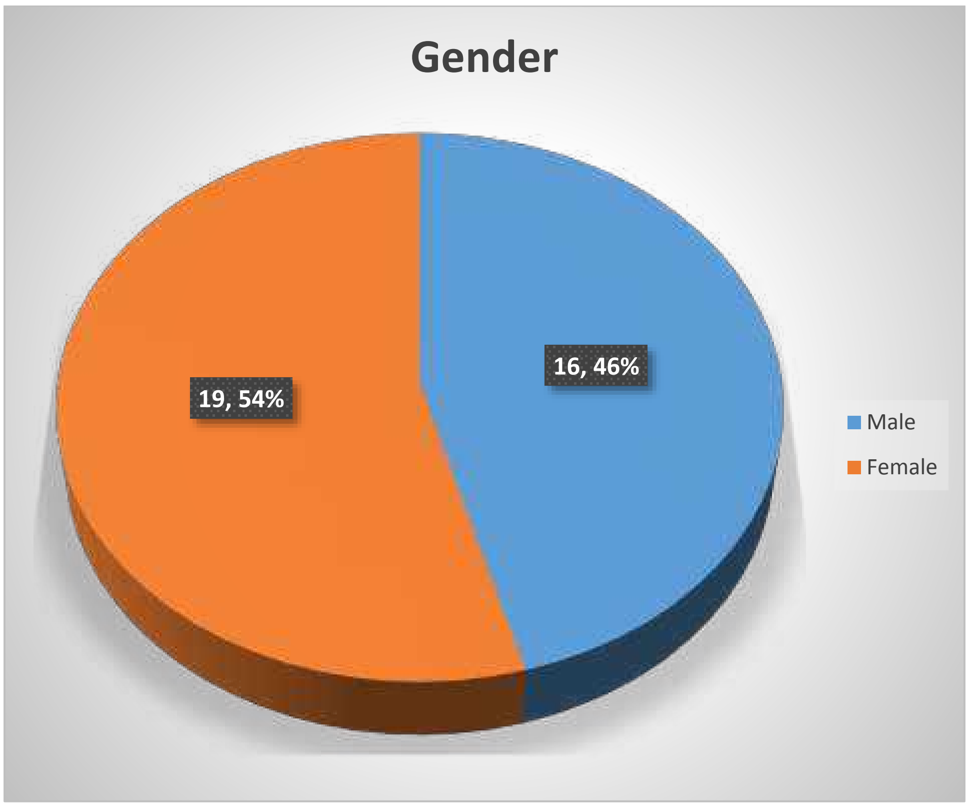


Figure 6: Gender

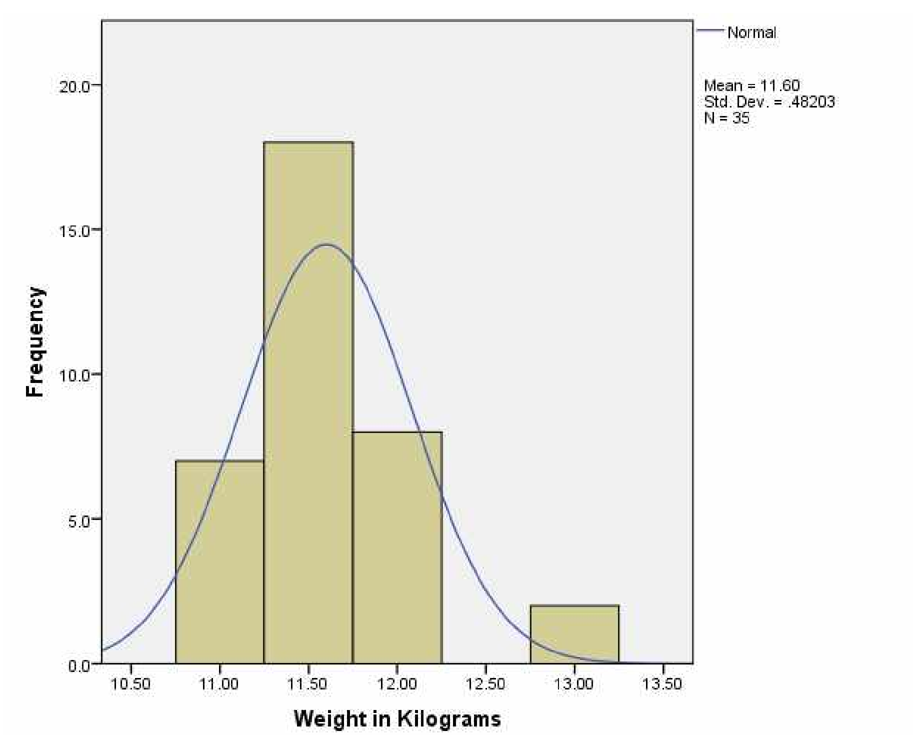
4.2.3. Patients' weight

The mean weight of the patients was 11.6 kilograms (95% CI; 10 to 13.2). The minimum weight was 11 kilograms while the maximum was 13 kilograms. The standard deviation was 482 grams. Table 3 and figure 7 below illustrate the descriptive statistics on the patients' weight.

Table 3: Weight distribution

	N	**Minimum**	**Maximum**	**Mean**		**Std. Deviation**	**Variance**
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Weight in Kilograms	35	11	13	11.6	0.08148	0.48203	0.232

Figure 7: Histogram for weight



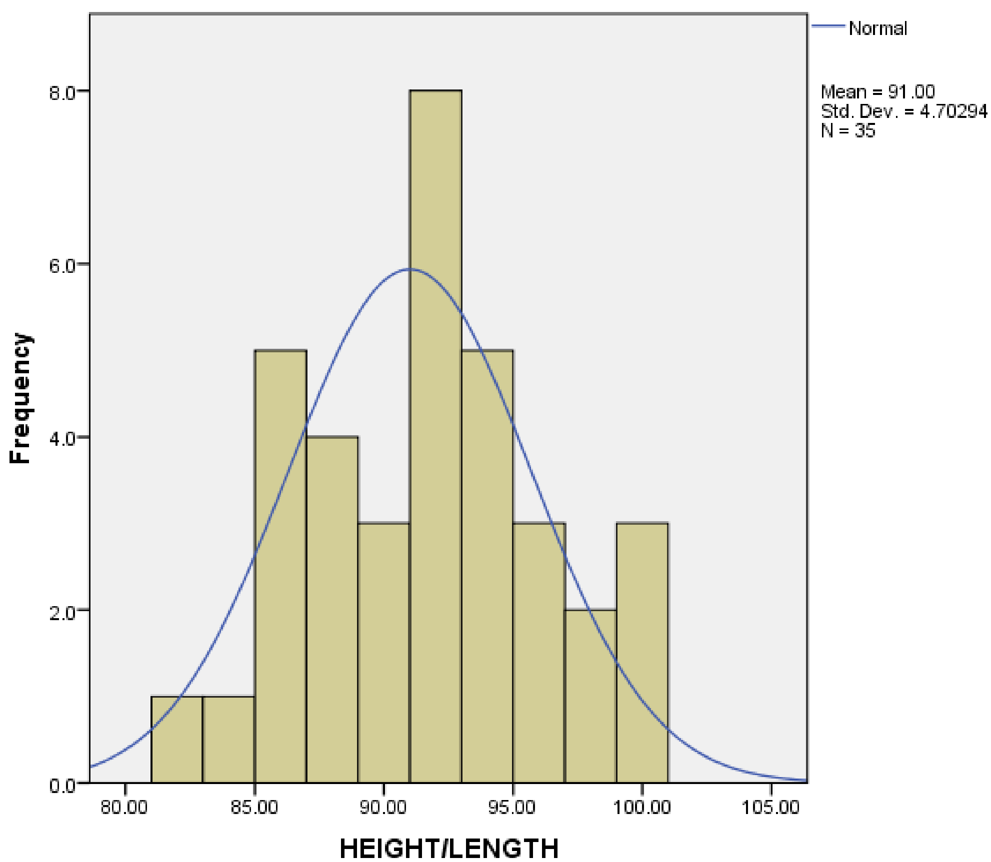
4.2.4. Patients 'height/length

The shortest patient was 82 centimetres while the tallest was 99 centimetres. The mean height was 91 centimetres (95% CI; 89.44 to 92.56). Table 4 and figure 8 below illustrate the height distribution.

Table 4: Height/length distribution

	N	**Minimum**	**Maximum**	**Mean**		**Std. Deviation**	**Variance**
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
HEIGHT/LENGTH	35	82	99	91	0.79494	4.70294	22.118

Figure 8: Histogram for Height/length distribution



4.3. Body Mass Index distribution

Approximately 49 % of the paediatrics treated with early spica casting were in the 1st percentile of paediatric BMI. More than half of the study population was in the 1st and 2nd percentile (57.2 %). The lowest BMI was 11.2, the highest was 17.1 and the mean was 14 (95% CI 13.53 to 14.4).

Table 5, Table 6 and figure 9 below illustrate the BMI distribution of paediatric patients treated with early spica casting at Kenyatta National Hospital for femoral shaft fractures.

Table 5: Descriptive statistics for BMI

	N	*Minimum*	*Maximum*	*Mean*		*Std. Deviation*	*Variance*
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
BMI	35	11.2	17.1	14.0343	0.23996	1.4196	2.015

Table 6: BMI distribution in percentiles

	Frequency	*%*	*Valid %*	*Cumulative %*
1st %ile	17	48.6	48.6	48.6
2nd %ile	3	8.6	8.6	57.2
5th %ile	2	5.7	5.7	62.9
17th %ile	1	2.9	2.9	65.8
18th %ile	2	5.7	5.7	71.5
25th %ile	2	5.7	5.7	77.2
26th %ile	1	2.9	2.9	80.1
27th %ile	1	2.9	2.9	83
33rd %ile	1	2.9	2.9	85.9
36th %ile	1	2.9	2.9	88.8
47th %ile	1	2.9	2.9	91.7
52nd %ile	1	2.9	2.9	94.6
66th %ile	1	2.9	2.9	97.5
84th %ile	1	2.9	2.9	100
Total	35	100	100	

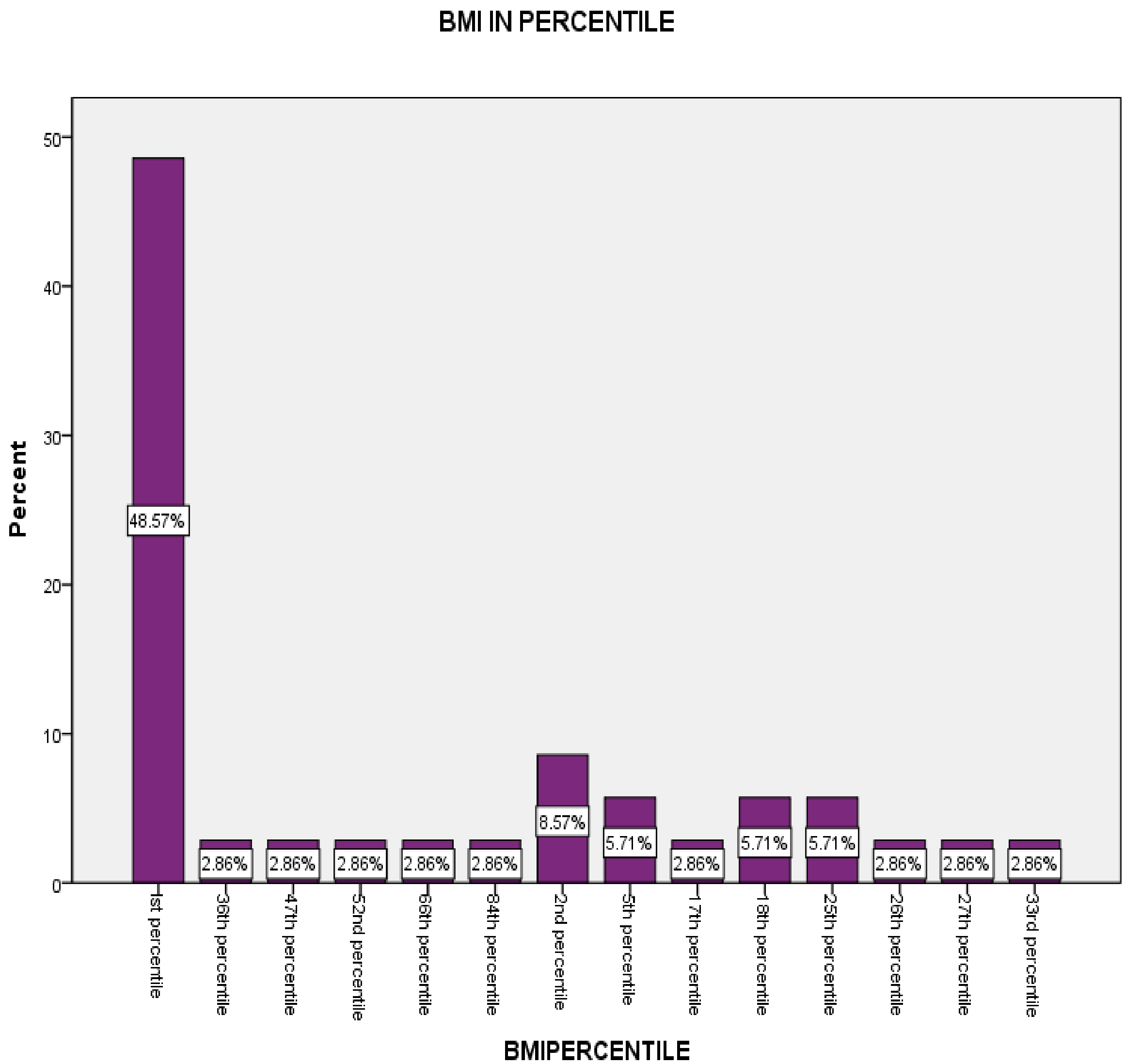


Figure 9: BMI distribution in percentiles

4.4. Common femoral shaft fracture patterns based on AO/OTA Classification

The most common femoral shaft fracture pattern based on AO/OTA classification was 3, 2, A2 at 37.1 % (n=13); followed by 3, 2, A3 at 22.9 % (n=8); 3, 2, A1 at 17.1 % (n=6); 3, 2, B2 at 11.4 % (n=4). These four classes contributed 88.6 % of the paediatric patients with femoral shaft fracture being treated by early spica casting. Classification 3, 2, B3 and 3, 2, B1 contributed 5.7 % each (n=2 each). Table 7 and figure 9 below show the femoral shaft fracture distribution based on AO/OTA classification.

Table 7: AO/OTA classification of femoral fracture distribution

	Frequency	%	Valid %	Cumulative %
3,2,A1	6	17.1	17.1	17.1
3,2,A2	13	37.1	37.1	54.3
3,2,A3	8	22.9	22.9	77.1
3,2,B2	4	11.4	11.4	88.6
3,2,B3	2	5.7	5.7	94.3
3,2,B1	2	5.7	5.7	100
Total	35	100	100	

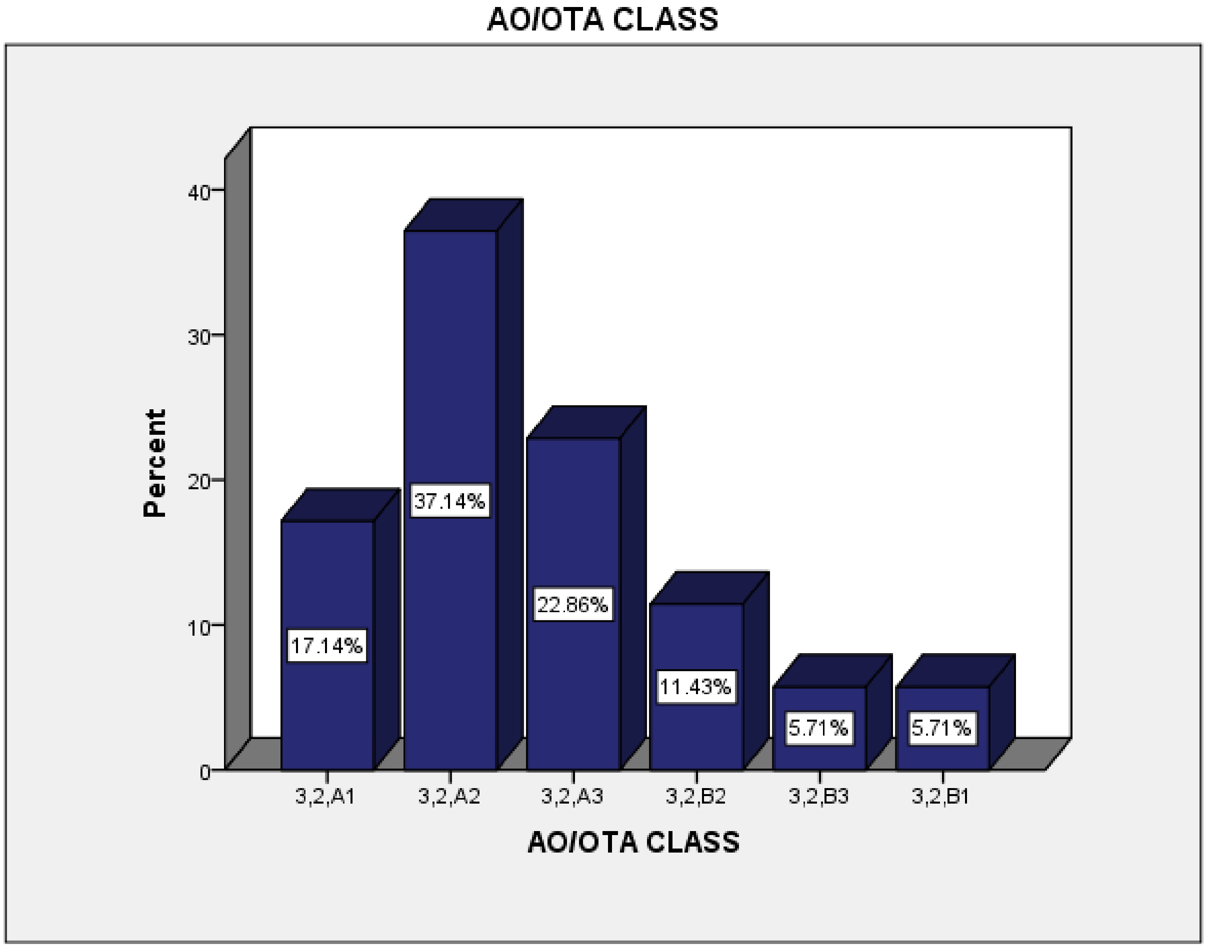


Figure 10: Bar graph of AO/OTA classification of femoral fractures distribution

4.6. The rate of LLLD after removal of the early spica cast

Limb discrepancy was present in 48.6 % (n=17) of the cases. In 45.7 % (n=16) of the cases, the limb length shortened by one (1) centimetre, while 2.9 % (n=1) shortened by two (2) centimetres. Table 8, table 9, figure 10 and 11 illustrate the distribution of limb length discrepancy after removal of the spica cast at the end of treatment.

Table 8: Occurrence of Limb length Discrepancy

	Frequency	%
Absent	18	51.4
present	17	48.6
Total	35	100

Table 9: Distribution of limb length discrepancy in centimetres

	Frequency	%	Valid %	Cumulative %
-2 Centimetres	1	2.9	2.9	2.9
-1 Centimetres	16	45.7	45.7	48.6
0 Centimetres	18	51.4	51.4	100
Total	35	100	100	

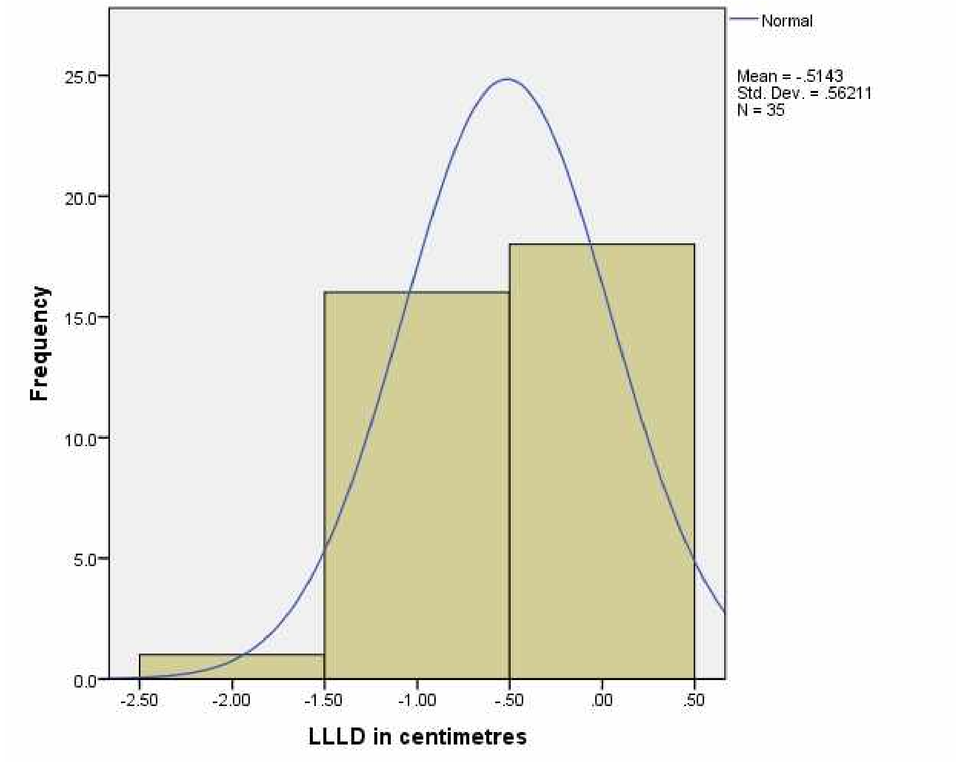


Figure 11: Histogram of LLLD distribution

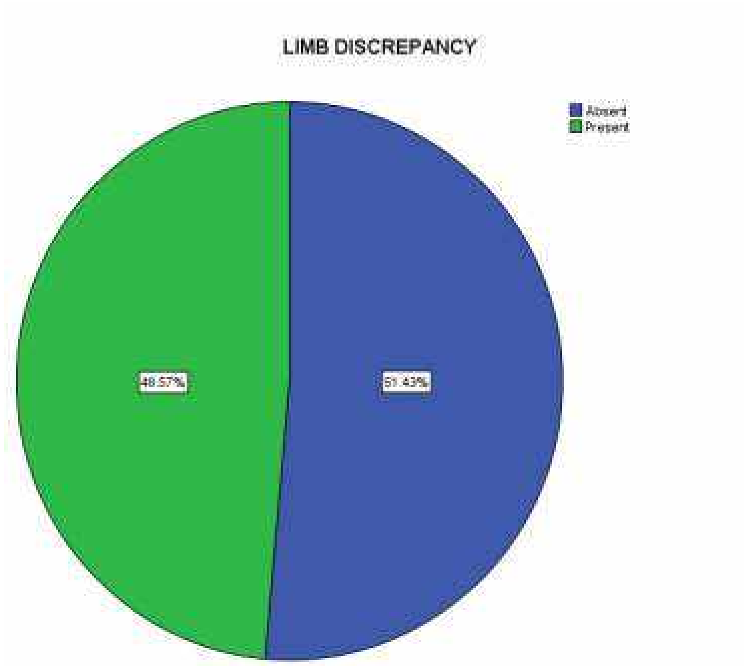


Figure 11: Pie chart showing the occurrence of LLLD

4.7. Relationship between BMI &LLLD

There is no statistically significant association between the BMI in percentiles and the limb length discrepancy (Chi-square value 13.673, D.F-26, P-value 0.997). There was no statistically significant relationship between the BMI and presence or absence of lower limb discrepancy. There was no relationship between BMI and presence or absence of LLLD (OR 1.38: Value 0.208). Table 10 and 11 below show the results.

Table 10: Chi-square test for relationship between BMI percentiles and LLLD

		LLLD in centimetres			Total	Chi-square Value	df	P-Value
		-2	-1	0				
BMI %ile	1st %ile	1	6	10	17	13.673	26	0.997
	36th %ile	0	1	0	1			
	47th %ile	0	1	0	1			
	52nd %ile	0	0	1	1			
	66th %ile	0	1	0	1			
	84th %ile	0	1	0	1			
	2nd %ile	0	1	2	3			
	5th %ile	0	1	1	2			
	17th %ile	0	1	0	1			
	18th %ile	0	1	1	2			
	25th %ile	0	0	2	2			
	26th %ile	0	1	0	1			
	27th %ile	0	0	1	1			
	33rd %ile	0	1	0	1			
Total		1	16	18	35			

Table 11: Binary Logistic regression on the relationship between BMI and presence/absence of LLLD

VARIABLES IN THE EQUATION							
		B	S.E.	Wald	df	Sig.	OR
STEP 1A	BMI	0.323	0.256	1.588	1	0.208	1.381
	Constant	-4.59	3.614	1.613	1	0.204	0.01

A VARIABLE(S) ENTERED ON STEP 1: BMI.

4.8. Relationship between fracture classification type (AO/OTA) & LLLD

There was no statistically significant relationship between the fracture classification type and lower limb length discrepancy in centimetres (Chi-square value 8.371, D.F 10, p-Value 0.593). There was no statistically significant relationship between the fracture classification type and the presence or absence of lower limb length discrepancy (Chi-square Value 4.167, DF 5 P-Value 0.526). Table 12 and 13 below illustrate these results.

Table 12: Relationship between fracture classification type (AO/OTA) and LLLD

		LLLD in centimetres			**Total**	**Chi-square value**	**DF**	**P-Value**
		-2	-1	0				
AO/OTA CLASS	3,2,A1	0	3	3	6	8.371	10	0.593
	3,2,A2	0	5	8	13			
	3,2,A3	1	2	5	8			
	3,2,B2	0	3	1	4			
	3,2,B3	0	2	0	2			
	3,2,B1	0	1	1	2			
Total		1	16	18	35			

Table 13: Relationship between fracture classification type (AO/OTA) and presence or absence of LLLD

		Presence or absence of limb discrepancy		Total			
		Absent	present		Chi-square Value	DF	P-Value
AO/OTA CLASS	3,2,A1	3	3	6	4.167	5	0.526
	3,2,A2	8	5	13			
	3,2,A3	5	3	8			
	3,2,B2	1	3	4			
	3,2,B3	0	2	2			
	3,2,B1	1	1	2			
Total		18	17	35			

4.9. Correlation between AO/OTA fracture class & LLLD

There was no statistically significant correlation between the fracture type classification and lower limb length discrepancy (Spearman's rho -0.173, P-value 0.32). Table 14 below illustrates the correlation coefficient.

Table 14: Spearman's correlation between Fracture type classification and LLLD

			AO/OTA CLASS	LLLD in centimetres
Spearman's rho	AO/OTA CLASS	Correlation Coefficient	1	-0.173
		Sig. (2-tailed)	.	0.32
		N	35	35
	LLLD in centimetres	Correlation Coefficient	-0.173	1
		Sig. (2-tailed)	0.32	.
		N	35	35

5.0. DISCUSSION

The occurrence of lower limb length discrepancy following spica cast treatment of femoral shaft fractures and the possible predisposing factors is not known in the Kenyan set up. This study is the first its kind at KNH and, therefore, it may be used to form a baseline for future references.

5.1. Age and Gender distribution

The peak age for femoral fractures treated by early spica casting was noted to be between 24 months to 42 months. The mean age was noted to be 34 months. This finding agrees with the study by Hedlund (25) which found the peak incidence of femoral paediatric fractures to be between one to three years. It also agreed with the study by Mutiso et al. (26) which found the peak incidence of paediatric femoral fractures to be between the ages of two and six years. The study also revealed that a majority of the paediatric femoral fracture patients being treated by early spica casting were females at 54 % compared to males at 46 %.

5.2. Height, Weight and BMI distribution

The mean weight of the participants was 11.6 kilograms while the average height was 91 centimetres. This enabled the researchers to calculate the BMI which revealed that majority of the patients were under weight. More than half of the study population was in the 1st and 2nd percentile (57.2 %). The lowest BMI was 11.2, the highest was 17.1, and the mean was 14. When these paediatric body mass indexes were matched for age and sex (percentiles); the study found that majority of the participants (48.6 %) were in the 1st percentile (underweight). Only 2.9 % was found to be overweight at 84th percentile. No patient was noted to be obese. This is almost similar to the study done by Gilbert et al. (31) that found only 1 % of their participants to have a BMI $\geq 95^{th}$ percentile (obese), although their study had majority of their patients at a normal BMI percentile and not underweight. The majority of the participants in our study being underweight could be attributed to the fact that KNH is a government run referral facility in a low income country. This type of facility mainly offers services to those from the lower social economic status who cannot afford private hospitals or health insurance. This is unlike the study done by Gilbert et al. (31) in two level I paediatric trauma centres in a middle-high income level country.

5.3. Fracture location and pattern (AO/OTA classification) distribution

The most common shaft fracture pattern based on AO/OTA classification was 3, 2, A2 at 37.1 % (n=13). This was followed by 3, 2, A3 at 22.9 % (n=8); 3, 2, A1 at 17.1 % (n=6); and 3, 2, B2 at 11.4 % (n=4). These four classes contributed 88.6 % of the paediatric patients with femoral shaft fractures being treated by early spica casting. Classification 3, 2, B3 and 3, 2, B1 contributed 5.7 % each (n=2 each). This fracture location distribution strongly agrees with a local study by Mutiso et al. (26) which found diaphyseal / shaft fracture to be the majority of the paediatric fractures at 82 % of their participants. In terms of the pattern, we noted a small proportion of comminuted patterns at 5.7 %, which was similar to the study by Mutiso et al. (26) at 12 %. This could possibly be attributed to the fact that the participants were of young preschool age, hence, their movements were mainly restricted to the area of residence. This results in low exposure to possible high energy injuries (that might cause comminution) such as motorbike or motor vehicle crush. Their patterns of injury could point to low energy mechanisms of injury. The fact that most of the fractures seen in this study were located on the diaphyseal / shaft, could be due to the fact that only children with this type of injury were selected for early spica cast while the rest (proximal or distal fractures) ended up under other forms of treatment such as surgical or traction. The findings on fracture location of this study strongly agrees with the study by Harigah et al. (30) which found majority of their participants having middle shaft fractures (75.7 %). Their study disagreed on the fracture pattern since this study mainly had oblique fracture patterns (3, 2, A2), while their study had a majority of spiral fractures (3, 2, A1) at 62.2 %. The study by Mehmood et al. (27) differed with this research since only a minority of their participants (32 %) had diaphyseal / shaft femoral fractures while the majority had proximal femoral shaft fractures.

5.4. Rate of limb length discrepancy after removal of the early spica cast

In this study, LLLD was present in 48.6 % (n=17) of the cases. In 45.7 % (n=16) of the cases the limb length shortened by one (1) centimetre, while 2.9 % (n=1) shortened by two (2) centimetres. The mean LLLD was found to be at -0.51 centimetres. Perfect outcome after conservative paediatric femoral is difficult to achieve as noted in similar other studies reviewed (27, 28, and 30). This is due to the technical challenge associated with application of the spica cast which requires skill and experience. Another reason could be due to the stringent follow-up protocol required after its application which some patients cannot fully adhere to. Clinically significant LLLD is that surpassing two centimetres because it leads to significant gait asymmetry and adversely affects the normal biomechanics of the spine (18). In this study, only one patient had an LLLD of 2 centimetres.

5.5. Relationship between Body Mass Index and LLLD

This study found no statistically significant association between the BMI in percentiles and lower limb length discrepancy in centimetres (Chi-square value 13.673, D.F-26, P-value 0.997). There was also no statistically significant relationship between the BMI and the presence or absence of limb discrepancy (OR-1.38: Value 0.208). This was contrary to the study by Hendersen et al. (33) which found obesity to be a relative contraindication of early spica casting for paediatric femoral fractures due to its association with development of LLLD. The difference between these two papers could be because none of the participants were found to be obese in the current research. Other studies reviewed also showed that obesity was a likely predictor of a paediatric patient failing spica casting and requiring surgery for a femoral fracture (31, 32).

5.6. Relationship between fracture classification type (AO/OTA) & LLLD

There was no statistically significant relationship between the AO/OTA fracture classification type and lower limb length discrepancy in centimetres (Chi-square value 8.371, D.F 10, p-Value 0.593). There was also no statistically significant relationship between the fracture classification type and the presence or absence of Limb length discrepancy (Chi-square Value 4.167, DF 5 P-Value 0.526).

There was no statistically significant correlation between the fracture type classification and lower limb length discrepancy (Spearman's rho -0.173, P-value 0.32).

This is similar to what Buehler et al. (28) and Harigah et al. (30) found in their studies. On the contrary, Mehmood and Shah (27) found an association between fracture location and development of LLLD. Majority of the LLLD cases in their study were found to have suffered mid femoral shaft fractures.

Despite the clinical guidelines from the American Academy of Orthopaedic Surgeons for the management of mid-shaft femoral fractures in the paediatric populations advising on delayed spica casting for unstable femoral shaft fractures, our findings suggest that paediatric femoral fractures can be safely managed using early spica casting. This is in regards to development of lower limb length discrepancy. However, a prospective study that encompasses a larger sample size is still needed to validate or refute this finding.

5.7. Conclusion

1. Children aged between 24 months to 42 months were most prone to the type of femoral fractures most likely to be treated by early spica casting.
2. Females were more likely than males to be affected in this respect.
3. The mean weight of the participants was 11.6 kilograms.
4. The average height of the affected children was 91 centimetres.
5. The lowest BMI was 11.2, the highest was 17.1 and the mean was 14.
6. BMI matched for age and sex (percentiles) found that majority of the participants (48.6 %) were in the 1^{st} percentile (underweight). None of the patients was noted to be obese (BMI $\geq 95^{th}$ percentile). This could be a possible indicator of the low socioeconomic status of most of the patients visiting this public hospital.
7. The most common femoral shaft fracture pattern based on AO/OTA classification was the 3, 2, A2 class. This was followed by the 3, 2, A3 class. This possibly meant

that a paediatric patient with a simple femoral diaphyseal/ shaft fractures was most likely to end up with treatment using an early spica cast.

8. LLLD following early spica cast was quite common (close to 50%) but was noted to be clinically insignificant (less than 2 centimetres) in majority of the cases.
9. There was no relationship between age and development of LLLD following treatment.
10. There was no relationship between BMI and development of LLLD following treatment.
11. There was no relationship between AO/OTA fracture classification and development of LLLD following treatment.
12. The results of treatment of paediatric femoral fractures with early spica casting were generally satisfactory with regards to limb length discrepancy for the period of this study.

5.8. Recommendations

1. The author recommends a larger sample size study with follow up period so that the findings can more adequately represent the general population.
2. Studies assessing the occurrence of other measures of poor outcomes following spica cast treatment of paediatric femoral shaft fractures should be done. These outcomes include malrotations and angulations plus their possible sequelae to the patient.
3. Studies assessing other possible factors predisposing the patients to LLLD should be done, for example; degree of initial fracture shortening.

REFERENCES

1. Beaty JH, Kasser JR. Rockwood & Wilkins' Fractures in Children. Sixth. Baltimore: Lippincott Williams & Wilkins; 2006.
2. Kenyatta National Hospital. Annual Report. Nairobi; 2000.
3. Kamienski MC. Paediatric femoral fractures. Orthop Nurs [Internet]. 2020;39(2):107—111.
4. Khoriati A-A, Jones C, Gelfer Y, Trompeter A. The management of paediatric diaphyseal femoral fractures: a modern approach. Strateg trauma limb Reconstr. 2016 Aug;11(2):87–97.
5. Crenshaw AH. Paediatric Fractures: fractures of femoral. In: Campbell's Operative Orthopaedics. 8th (Vol.2) Mosby Yearbook Inc; 1992. p. 1181.
6. Appley AG, Solomon L. Fractures of the femoral: Mechanism of Injury. In: Appley's System of Orthopaedics and fractures. 7th Edition. Butterworth Heinemann Ltd; 1993. p. 663–665.
7. Anglen JO, Choi L. Treatment options in paediatric femoral shaft fractures. J Orthop Trauma. 2005;19(10):724–33.
8. D'Ollonne T, Rubio A, Leroux J, Lusakisimo S, Hayek T, Griffet J. Early reduction versus skin traction in the orthopaedic treatment of femoral shaft fractures in children under 6 years old. J Child Orthop. 2009 Jun 1;3:209–15.
9. Flynn JM, Skaggs DL, Sponseller PD, Ganley TJ, Kay RM, Leitch KK. The surgical management of paediatric fractures of the lower extremity. Instr Course Lect . 2003;52:647—659.

10. Buckley SL. Current trends in the treatment of femoral shaft fractures in children and adolescents. Clin Orthop Relat Res. 1997 May;(338):60–73.

11. Parsch KD. Modern trends in internal fixation of femoral shaft fractures in children. A critical review. J Pediatr Orthop B. 1997 Apr;6(2):117–25.

12. Mckeon K, Smith J, Gordon J. Paediatric femoral shaft fractures: Current and future treatment. Int J Clin Rheumtol. 2010 Dec 1;5:687–97.

13. Moore RA, Schafer EW. Treatment of simple fractures of the shaft of the femoral by a fixed traction Spica; a preliminary report. N C Med J. 1948 Oct;9(10):514–9.

14. Ferguson J, Nicol R. Early Spica Treatment of Paediatric Femoral Shaft Fractures. J Pediatr Orthop. 2000;20:189–92.

15. Monthir G, Hameed J. Assessment of outcome of early versus delayed Spica cast treatment of closed femoral shaft fractures in children. Int J Adv Res Biol Sci. 2018;5 (5):63–73.

16. Cashman J, Goyal N, Parvizi J. Hip Spica Cast [Internet]. Wheeless Textbook of Orthopaedics.

17. Pappas AM, Nehme AM. Leg length discrepancy associated with hypertrophy. Clin Orthop Relat Res. 1979; (144):198–211.

18. Corry IS, Nicol RO. Limb length after fracture of femoral shaft in children. J Pediatr Orthop. 1995;15:217-9.

19. Martinez AG, Carroll NC, Sarwark JF, Dias LS, Kelikian AS, Sisson GAJ. Femoral shaft fractures in children treated with early Spica cast. J Pediatr Orthop. 1991;11(6):712–6.

20. James BH, James KR. Rockwood & Wilkins' Fractures in Children. 6th edition. Lippincott Williams & Wilkins. 2006:901.

21. Corry IS, Nicol RO. Limb length after fracture of femoral shaft in children. J Pediatr Orthop. 1995;15:217-9.

22. Sabharwal S, Kumar A. Methods for assessing leg length discrepancy. Clin Orthop Relat Res. 2008;466(12):2910-2922.

23. Rondon CA, Gonzalez N, Agreda L, Millan A. Observer agreement in the measurement of leg length. Rev Invest Clin. 1992;44:85–89.

24. Beattie P, Isaacson K, Riddle DL, Rothstein JM. Validity of derived measurements of leg-length differences obtained by use of a tape measure. Phys Ther. 1990 Mar;70(3):150-7.

25. Hedlund R, Lindgren U. The incidence of femoral shaft fractures in children and adolescents. J Pediatr Orthop. 1986;6(1):47–50.

26. Mutiso VM, Ng'ang'a E, Mwangi JC. Pattern of long bone fractures in a paediatric population at Kenyatta National Hospital. East African Orthop J [Internet]. 2017;11(2):54–60.

27. Mehmood M, Shah S, Razzaq S. Frequency of limb shortening in femoral shaft fractures treated by hip Spica casting in children in Tertiary Care Hospital. Prof Med J. 2019 Nov 10;26:1873–7.

28. Buehler KC, Thompson JD, Sponseller PD, Black BE, Buckley SL, Griffin PP. A prospective study of early Spica casting outcomes in the treatment of femoral shaft fractures in children. J Pediatr Orthop [Internet]. 1995;15(1):30—35.

29. Cassinelli EH, Young B, Vogt M, Pierce MC, Deeney VF. Spica cast application in the emergency room for select paediatric femoral fractures. J Orthop Trauma. 2005 Nov-Dec;19(10):709-16.

30. Hariga H, Mousny M, Docquier PL. Leg length discrepancy following femoral shaft fracture in children: clinical considerations and recommendations. Acta Orthop Belg. 2011 Dec;77 (6):782-7.

31. Gilbert SR, MacLennan PA, Backstrom I, Creek A, Sawyer J. Altered lower extremity fracture characteristics in obese paediatric trauma patients. J Orthop Trauma. 2015 Jan;29(1).

32. Neill Y. Li, Aristides Cruz, Saisanjana Kalagara, Alicia Hersey, Alan Daniels. The Influence of Obesity on the Operative and Non-Operative Management of Paediatric Extremity Fractures. Journal of the American Academy of Paediatrics. 2019 Aug 144 (2).

33. Henderson OL, Morrissy RT, Gerdes MH, McCarthy RE. Early casting of femoral shaft fractures in children. Journal of Paediatric Orthopaedics. 1984 Jan;4(1):16-21.

34. Jain A, Aggarwal A, Gulati D, Singh MP. Controversies in Orthopaedic Trauma-Management of Fractures of Shaft of Femoral in Children Between 6 and 12 Years of Age. Kathmandu Univ Med J 2014;45(1):77-84.

35. American Academy of Orthopaedic Surgeons Board of Directors. Treatment of paediatric diaphyseal femoral fractures evidence-based clinical practice guideline. 2015 June.

36. Frech-Dörfler M, Hasler CC, Häcker F-M. Immediate hip Spica for unstable femoral shaft fractures in preschool children: still an efficient and effective option. Eur J Pediatr Surg Off J Austrian Assoc Pediatr Surg . [et al] = Zeitschrift fur Kinderchirurgie. 2010 Jan;20(1):18–23.

37. Czertak DJ, Hennrikus WL. The treatment of paediatric femoral fractures with early 90-90 Spica casting. J Pediatr Orthop. 1999 Mar-Apr;19(2):229-32.

38. Epps HR, Molenaar E, O'connor DP. Immediate single-leg Spica cast for paediatric femoral diaphysis fractures. J Pediatr Orthop. 2006 Jul-Aug;26(4):491-6.

39. Borg, W. R., & Gall, M. (1979). Educational Research: An Introduction (3rd ed.). New York: Longman.

APPENDICES

APPENDIX A: Data Collection Sheet /Questionnaire

Date: -------------------------------

PATIENT BIODATA

1) STUDY NUMBER
2) AGE
3) SEX

   MALE FEMALE

FRACTURE LOCATION/PATTERN (AO/OTA CLASSIFICATION)

4) What is the fracture AO/OTA class?

LOWER LIMB	RIGHT	LEFT
Femoral AO/OTA classification		

BODY MASS INDEX

5) BMI=

LIMB LENGTH AFTER TREATMENT COMPLETION

6) Limb measurements in centimetres

Fractured limb (cm)………..

Normal limb (cm)…………..

a) Limb Length discrepancy (with respect to normal limb)……….

APPENDIX B: (Consent form in English)

INFORMED CONSENT

Title of the study: LIMB LENGTH DISCREPANCY AND PREDISPOSING FACTORS AFTER TREATMENT OF PAEDIATRIC FEMORAL SHAFT FRACTURES WITH EARLY SPICA CASTING AT THE KENYATTA NATIONAL HOSPITAL.

Principal Researcher: Dr. Michael Wachira Kariuki (Senior House Officer-M.MED Orthopaedics, University of Nairobi).

The informed consent contains 3 parts:

1. Information sheet
2. Certificate of consent
3. Statement by the researcher

PART 1: INFORMATION SHEET

TITLE:

INVESTIGATORS STATEMENT

I am Dr. Michael Wachira Kariuki. I am conducting a study to find out the rate of lower limb length discrepancy and predisposing factors after treatment of paediatric femoral shaft fractures with early spica casting at the Kenyatta national hospital. I am requesting you to participate in this study and the purpose of this form is for you to decide whether to participate or not.

Kindly read through the form carefully and feel free to address any queries or concerns regarding the study to me.

This study has been approved by the KNH/UON Ethics and Research Committee protocol number P675/12/2020.

I, the investigator, will be available for any clarifications while filling the form and thereafter.

BRIEF DESCRIPTION OF THE STUDY

This study is meant to establish the rate of limb discrepancy after treatment of femoral shaft fracture with Spica casting in paediatric patients. It will also investigate the associated predisposing factors for development of this complication. The findings of this study will be used to improve the care given to such patients in the future.

PARTICIPATION

If you choose to participate in the study, you will be handed a questionnaire to fill on behalf of your child. This should take not more than 10 minutes of your time.

The questionnaire will cover participant's information,

The data collected will remain anonymous and will be stored securely.

RISKS INVOLVED IN THE STUDY

No risks or adverse events have been identified in participating in the study, no personal identifying information will be collected and data will remain anonymous and cannot be traced back to your child.

BENEFITS OF PARTICIPATING IN THE STUDY

The information gathered will provide new insight on the outcomes of Spica casting treatment at Kenyatta National Hospital.

QUESTIONS AND CHOICES

You are free to address any questions to the principal investigator via the contact information provided at the end of this document. Your participation is wholly voluntary and you may choose to decline your child's participation in the study or withdraw their participation at any stage without any repercussions.

PART 2: CERTIFICATE OF CONSENT

PARTICIPANT'S STATEMENT

I have fully read this consent form or had the contents read to me. My questions, if any, have been answered in a language that I understand. The risks and benefits have been explained to me. I understand that my child's participation in this study is completely voluntary and I may choose to withdraw him/her at any time without repercussions. I freely choose to enrol my child into this study.

Signed…………………………………. Date………………………….

PART 3: RESEARCHER'S STATEMENT

I, the undersigned have fully explained the relevant details of this research study to the participant and believe the participant has understood and has freely and willingly given his/her consent on behalf of their child.

Researchers name: ………………………………………………

Signature: ……………………………………… Date:

……………………………………………

For more information, contact:

- **Principal researcher:**

  Dr Michael Wachira Kariuki

  Senior house officer-MMed Orthopaedics, Department of surgery

  School of medicine, UoN.

  P.O. Box 00100-27536, GPO.

  Tel: 0722496729

- Secretary, KNH/UoN-ERC

  P.O. Box 20723 K.N.H, Nairobi 00202

  Tel: 020726300-9

Email: uonknh-erc@uonbi.ac.ke

APPENDIX C: (Consent form in Swahili)

FOMU YA MAKUBALIANO KUSHIRIKI KATIKA UTAFITI

Sehemu ya Kwanza: Faharasa/Dibaji

Utangulizi

Majiraha ya kuvunjika mifupa kwa watoto ni shida kubwa katika mataifa yanayoendelea, ikiwemo Kenya. Majiraha haya yasipotibiwa kwa dharura, huenda yakapunguza thamani ya maisha ya mhudhuriwa na hata kusababisha kifo. Tunakuomba ushiriki katika utafiti huu wa kufumbua matokeo ya matibabu kutumia mbinu ya Spica cast.

Tunakuomba usome fomu hii na uulize maswali yoyote ambayo unaweza kuwa nayo kabla ya kukubali mtoto wako kushiriki katika utafiti huu.

Sababu za utafiti

Kusudi la utafiti huu ni kufumbua matokeo ya matibabu kutumia mbinu ya Spica cast kwa majiraha ya kuvunjika mfupa wa paja kwa watoto. Matokeo ya utafiti huu yatatumika kutengeneza dimbwi la data litakalo tumiwa kwa uundaji wa sera ambazo zitasaidia katika matibabu ya jeraha hili.

Maelezo ya Utafiti

Mara baada ya kukubali mtoto wako kushiriki katika somo hili, utaruhusiwa kuuliza maswali yoyote kuhusu utafiti na kuongeza matatizo yoyote ambayo unaweza kuwa nayo. Mara baada ya kuridhika na majibu uliyopokea, utahitaji kusaini fomu ya idhini.

Mtafiti mkuu atakupa dodoso litakalochukua historia ya kidemografia na historia ya majeraha.

Hatari zinazohusika

Utafiti huu hautakuathiri vibaya kwa namna yoyote na hakuna mashtaka yaliyofichika katika ushiriki wa mtoto wako. Matibabu hayaondolewi ikiwa hushiriki.

Faida

Taarifa tunayopata itatusaidia kuongeza maarifa kuhusa huu ugonjwa pamoja na kutengeneza dimbwi la data liatakalo tumika kwa uundaji wa sera.

Siri

Jina la mtoto wako halitaonekana kwenye nyaraka yoyote na namba ya usajili tu itatumika kama alama ya kutambua.

Matumizi ya Data

Kama habari zote za kisayansi tunatafuta kushiriki matokeo yetu na watu wengine wanaofanya masomo kama hayo. Kwa hiyo, matokeo yatatolewa katika mikutano ya kisayansi na kuchapishwa katika majarida ya kisayansi.

Uhuru

Unaweza kuondoa mtoto wako kwa hiari wakati wowote bila adhabu yoyote.

Tamko la Mtaalamu Mkuu

Mimi kama mchunguzi mkuu natangaza kuwa hakuna malipo ya kifedha niliopokea wala wasimamizi au hospitali ya Taifa ya Kenyatta kutoka kwa kampuni yoyote ya dawa au robo nyingine yoyote ili kujifunza utafiti huu.

Tafadhali jisikie huru kutafuta maelezo ya ziada kupitia anwani zilizopewa chini;

- **Principal researcher:**

  Dr Michael Wachira Kariuki

  Senior house officer-Mmed Orthopaedics, Idara ya Upasuaji wa Mifupa,

  Shule ya Matibabu, UoN.

  S.L.P 00100-27536, GPO.

  Namabari Ya Simu: 0722496729

- **Katibu, KNH/UoN-ERC**

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  Namabari ya Simu: 020726300-9

  Barua pepe: uonknh-erc@uonbi.ac.ke

  Tovuti: http://www.erc.uonbi.ac.ke

Sehemu ya Pili: Fomu ya Makubaliano

Nimeelezwa utafiti huu kwa kina. Nimekubali moto wangu kushiriki utafiti huu kwa hiari yangu. Nimepata wakati wa kuuliza maswali na nimeelewa kuwa ninapo maswali zaidi, ninaweza kumuuliza mtafiti mkuu au watafiti waliotajwa hapo awali.

Jina la Mshiriki……………………………………………………………….

Sahihi ya Mshiriki…………………………………………………………….

Tarehe…………………………………………………………………………

APPENDIX D: AO/OTA Classification System (Femoral fractures)

AO/OTA fracture classification: This is a concise and streamlined system of classifying fractures based on their anatomical location. It was published in 2006 after the Orthopaedic Trauma Association Committee for classification and coding published a revision of their 1996 fracture map system by combining it with the Muller/AO fracture classification system of 1987.

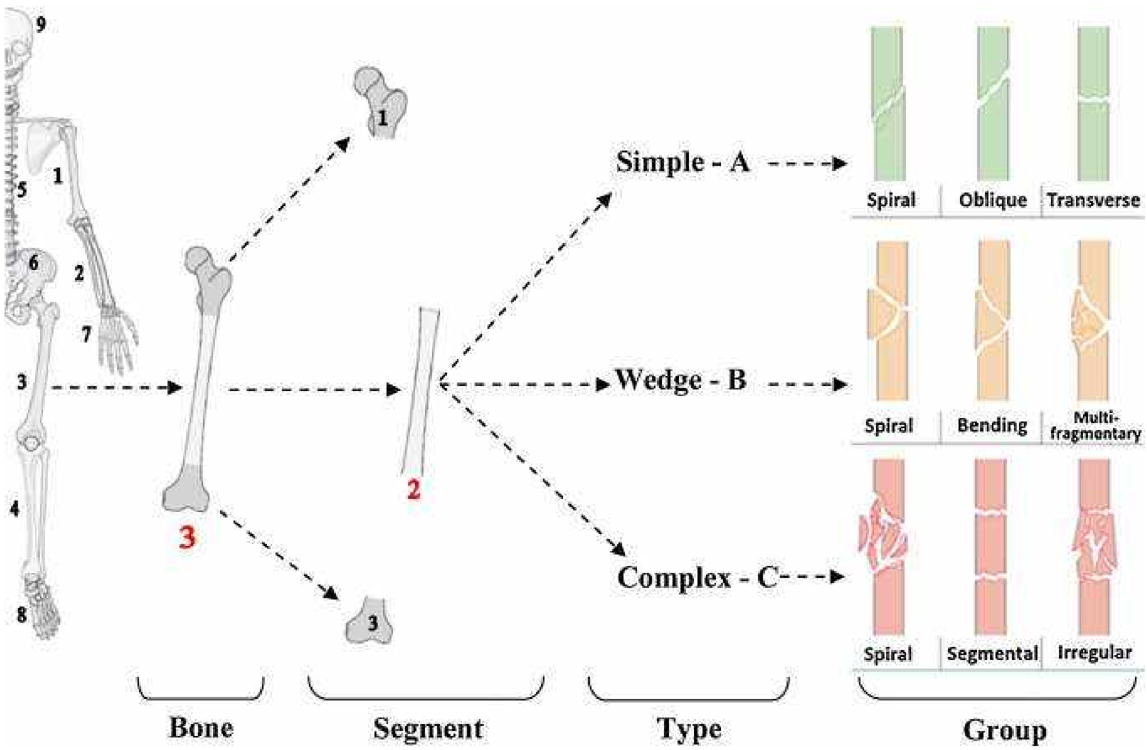

Figure 12: AO/OTA classification for femoral fractures

APPENDIX E: Spica Cast Application Process

Table 15: Spica cast application method (adapted with permission from https://www.wheelessonline.com/joints/hip/hip-Spica-cast/)

Table 1: Application of Spica Casting as Described in the Wheeless Textbook of Orthopedics

i) Timing: Immediate / early usage (within 24 hours of child arriving in hospital) or delayed with one and a half spica cast for pediatric femoral diaphysis fractures. The choice between early or delayed spica casting depends on the local experience of the team managing the patient.

ii) Position of Spica:

- Place affected thigh in 10 degrees of abduction or in neutral position with opposite hip in moderate abduction to facilitate perineal hygiene;
- To decrease muscle forces & to minimize amount of shortening, place the lower extremity in the relaxed position by;
  - putting hip flexion, abduction, external rotation & knee flexion
  - common mistake is to place the fractured thigh in marked abduction with resulting
- To prevent lateral bowing due to the pull of strong adductors;
  -consider placing the limb in the correct position before application of spica;
  -proximal 1/3rd fractures position: - hip flexion: 45 degrees; - hip abduction: 30 degrees - external rotation: 20 degrees
  - mid shaft fractures position: - hip flexion: 30 degrees; - hip abduction: 20 degrees - external rotation: 15 degrees
  - distal 1/3rd fractures position: - hip flexion: 20 degrees; - hip abduction: 20 degrees - external rotation: 15 degrees

iii) Contraindications:
unacceptable initial shortening or angulation (shortening more than 3 cm); open fractures; thoracic or intra-abdominal trauma; large or obese children (inability for parents to care for child)

iv) Technique:

- padding

- place a folded towel on the anterior thorax and abdomen and apply all padding and casting material over this towel;
- following cast application the towel is removed
- This will create space between the cast and the thorax/abdomen and will avoid cast tightness and difficulty with breathing;
- using this technique, it is not necessary to window the abdomen of the cast;
- It is useful to place 2 layers of body stockingette over the patient's torso to ensure that the cast padding can be pulled up over the edges of the cast;
- gortex soft wool wrap is preferable to cotton wrap (gortex can be cleaned if it gets soiled);
- soft wrap (preferably Gortex) is placed, w/ care to evenly spread the cotton across the back and buttocks (including sacrum);
- a thick belt of felt is taped across the chest, just below the nipple line;
- a second felt belt is fashioned to cover the sacrum, posterior superior iliac spine, and anterior inferior iliac spine

- reduction:

- prior to cast application, use flouroscopy to help determine the optimal position for reduction;
- distal femoral traction pin is inserted if fracture needs to be brought out to length;
- apply the cast, but apply minimal cast material around the injured thigh;
- once the cast is hard, bring in flouroscopy and determine if the reduction is adequate or do a check xray;
- if the reduction is not adequate, then circumferentially cut the cast at the level of the fracture;
- then re-reduce the fracture under flouroscopic control if possible;
- once the reduction is adequate, have an assistant quickly apply more casting material while the thigh is held in the reduced position;

- cast re-enforcement:

- apply a "broom stick" between the thighs and apply cast material over this, in order to strengthen the cast and prevent cast breakdown at the hip joint;

v) Cast Care:

- goretex liner allows the child and the cast to be washed; a panty shield napkin can be applied to the perineum to prevent soiling of the cast;
- child is seen every 2 weeks for evidence of skin break down

Adapted with permission from Wheeless Textbook of Orthopedics (20)

APPENDIX F: Study instruments/tools

Figure 13: TRACK® Analog Salter Type Baby Weighing Scale

Figure 14: Seca® 213 stadiometre

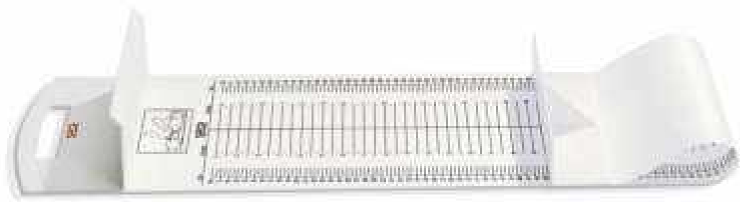

Figure 15: Seca® 416 infantometre

APPENDIX G: ETHICAL APPROVAL

UNIVERSITY OF NAIROBI
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APPROVED 08 MAR 2021 KNH/UoN-ERC

Ref: KNH-ERC/A/86

8th March 2021

Dr. Michael Wachira Kariuki
Reg. No.H58/87978/2016
Dept.of Orthopaedic Surgery
School of Medicine
College of Health Sciences
University of Nairobi

Dear Dr. Wachira

RESEARCH PROPOSAL – OCCURRENCE AND FACTORS PREDISPOSING TO LOWER LIMB LENGTH DISCREPANCY FOLLOWING TREATMENT OF PAEDIATRIC FEMUR SHAFT FRACTURES WITH EARLY SPICA CAST AT THE KENYATTA NATIONAL HOSPITAL (P675/12/2020)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and **approved** your above research proposal. The approval period is 8th March 2021 – 7th March 2022.

This approval is subject to compliance with the following requirements:

a. Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b. All changes (amendments, deviations, violations etc.) are submitted for review and approval by KNH-UoN ERC before implementation.
c. Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
d. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e. Clearance for export of biological specimens must be obtained from KNH- UoN ERC for each batch of shipment.
f. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
g. Submission of an *executive summary* report within 90 days upon completion of the study. This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

Protect to discover

For more details consult the KNH- UoN ERC website **http://www.erc.uonbi.ac.ke**

Yours sincerely,

PROF. M. L. CHINDIA
SECRETARY, KNH-UoN ERC

c.c. The Principal, College of Health Sciences, UoN
The Senior Director, CS, KNH
The Chairperson, KNH- UoN ERC
The Assistant Director, Health Information Dept, KNH
The Dean, School of Medicine, UoN
The Chair, Dept. of Surgery, UoN
Supervisors: Dr. Kirsteen Ondiko Awori, Dept. of Human Anatomy, UoN
Dr. George K. Museve, Dept.of Orthopaedic Surgery, UoN

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