RE-DISPLACEMENT OF CLOSED DIAPHYSEAL FOREARM FRACTURES IN CHILDREN TREATED BY ABOVE ELBOW CAST AT KENYATTA NATIONAL HOSPITAL

Dissertation submitted in partial fulfillment of the requirements for award of the degree of Master of Medicine (MMed) in Orthopaedic Surgery of the University of Nairobi.

DR. ADMANI ARIF MOHAMED. R

H58/69101/2013

Declaration:

This is to certify that this dissertation is my original work and has not been presented for a degree course in any other university.

Signature: ________________________ Date: ___________________________

Dr. Arif Admani.

0710584111

Supervisors

This is to certify that the study was undertaken under our guidance and supervision and that this book was submitted with our approval as the university supervisors.

DR. VINCENT MUOKI MUTISO

Consultant Orthopaedic surgeon

Chairman - Department of Orthopaedic Surgery, University of Nairobi

Signature: _______________ Date: ____________________

DR. TOM MOGIRE

Consultant orthopaedic surgeon

Lecturer Department of Orthopaedic Surgery, University of Nairobi

Signature:________________ Date:______________________

Certificate of Authenticity

This is to certify that the work identified below is the original work of the author.

DR. VINCENT MUOKI MUTISO

Chairman Department of Orthopaedic Surgery

University of Nairobi

Signed: ________________

Date: __________________

Contents

List of Abbreviations

KNH – Kenyatta National Hospital

A & E – Accident and Emergency

CRF – Case Report Form

IOM – Intra-Osseous Membrane

LAR – Legally Acceptable Representative

BMI – Body Mass Index

ERC – Ethics and Research committee

UoN – University of Nairobi

SOP – standard operation protocol

AP – Anteroposterior

ACL – Anterior Cruciate Ligament

CT – Computed Tomography

Definition of terminologies

Skeletally immature: Growth plates of children or adolescents that have not fully closed.

Closed reduction*:* Aligning or straightening a broken bone without surgically exposing it.

Acceptable reduction: Agreed position of bone alignment after attempted straightening of a fractured bone according to Wilkins et al

Re-displacement: Loss of reduction or alignment for a fracture that has initially been reduced.

Cast immobilization: Keeping the fractured limb in a contoured cast e.g. Plaster of Paris to maintain reduction until healing occurs.

Legally acceptable representative*:* A minor's parent or guardian who is capable of consenting for such a minor.

Childhood: Children within the age group of (2-13) years

Cast Index: A ratio of the saggital width to the coronal width of the plaster cast at the level of the fracture site as seen on X-rays.

Abstract

Background

Diaphyseal forearm fractures are the third most common paediatric fractures and are mostly managed conservatively. Following casting, re-displacement is the most common short term complication. Lack of correction of the re-displacement leads to maluinon of the fractured forearm bones, with limitation of function. Maintenance of acceptable reduction after casting is difficult and various predictive factors have been previously identified, however, no literature exists on the forearm shafts Re-displacement in Kenya to date. Knowledge of re-displacement and predictive risk factors will enable prompt identification of high risk patients and initiate alternative methods of treatment.

Objective

To determine the Re-displacement rate and risks in casted diaphyseal forearm fractures in childhood.

Design

Prospective observational study

Setting

KNH A&E, orthopaedic clinic and paediatric orthopaedic wards

Patients and Methods

Children aged between 2 and 13 years with consenting legally acceptable representative (LAR) presenting in KNH with closed diaphyseal forearm fractures were recruited for the study at KNH. Information was obtained from interviews with the children and their LAR, patients' files and patients' x-rays. Radiographic information was obtained from pre-reduction, immediate post reduction and two weeks post reduction x-ray films. Data collected was analysed using SPSS version 23.

Data management/analysis

All questionnaires were checked and assessed for completeness before data entry. These questionnaires were stored under lock and key in a cabinet. Data was entered into a password

coded database accessible only to the Data Clerk and the Principal Investigator. Once data entry was complete, the entered data was assessed for accuracy and identified entry errors corrected.

Exploratory data was thereafter analysed to identify any irregularities and extreme values. For description of the study population, fractures and re-displacement, categorical variables were summarized by means of counts and percentages using frequency tables while continuous variables were summarized by use of measures of central tendency and dispersion (mean, standard deviation, median, minimum, maximum, range, IQR).

Determination of factors associated with redisplacement, chi-squared tests were applied for categorical variables and analysis of variance (ANOVA) tests were done for continous variables. Logistic regression was thereafter applied to determine independent factors associated with redisplacement.

Presentation of results was by use of tables, graphs, charts and text narratives.

Results

Fifty-two patients were recruited into this study. These were 40 males and 12 females with a male female ration of 3.5:1 (Figure 1). The mean age of the patients was 9±2years. Most (80.8%) of the patients were right hand dominant. The most common cause of the injury was a fall onto a level ground during playing (N=44), the rest fell from a height. At two weeks post casting, the re-displacement rate was 29% (N=15). Most fractures were complete (69%) and involved the middle segment (70%) of the bones. The cast index of 0.7 - 0.81 was observed in 70% of the cases. Most (85%) of the patients who had redisplacements had a cast index of > 0.81. Taller, older, heavier patients redisplaced their fractures compared to their counterparts. Most redisplaced fractures were in the distal segment of the bones. Higher precasting translation of both bones predicted redisplacement.

Conclusion

The total rate for redisplacement was 28.8% in this study. Factors found to be significant contributors towards redisplacement of diaphyseal forearm fractures in children include: age of the patient, height of the patient, weight of the patient, quality of the plaster mold for immobilization as measured by the cast index and initial translation of the radius and ulna.

Literature Review

Introduction

Forearm shaft fractures account for about 33% of all bone fractures in children [1], [2]. The incidence of these fractures has been noted to be increasing in the last few years [3], [4].

Pediatric fractures present significant challenges to the orthopedic community. Epidemiologic studies have shown that 18% of children will experience a fracture by the age of 9, with children between the ages of 5 and 14 having the highest fracture incidence. Male to female ratio is roughly 3:2, due to the increased play activities in the male child, however, the average age for females is (9-11), while for boys is (11-14).

Fractures of the shaft of the radius and ulna may occur in the distal third, middle third, or upper third. Fractures are more common distally than proximally, this is due to the structural anatomy whereby the distal radius is flattened as compared to the proximal radius which is cylindrical [5]. The reduced envelope of protective muscle cover distally as compared to the proximal forearm also contributes to the increased incidence of distal fractures.

Fractures may be greenstick or complete in both the radius and ulna, or they may be complete in one and greenstick in the other. Complete fractures may be undisplaced, minimally displaced, or markedly displaced with overriding and angulation. Angulation may be volar, dorsal, medial or lateral to the interosseous space. Plastic deformation of one or both bones of the forearm may occur.

Most of these fractures are treated conservatively by manipulative reduction and cast immobilization [5], [6].
During conservative management, the most commonly encountered complication is fracture re-displacement, which if left to heal that way, causes malunion of the fracture ends, consequentially impairing forearm rotation [7], [8], [9], [10].
Knowledge of potential predictors of re-displacement can improve the effectiveness of cast immobilization and thereby help in identification of patients who are candidates for surgical fixation rather than closed management [8], [9], [10]. Most of the recent studies on forearm fractures have focused on the rate of re-displacement following conservative management of distal metaphyseal radius fractures [11], [12], [13], however, limited data is available on the outcome of diaphyseal forearm fractures in children. Bowman et al.conducted a retrospective study of children with both-bone forearm shaft fractures who were managed conservatively. In their study, they concluded that 50% of children experienced re-displacement over 4 weeks of follow-up, with up to 95% occurring within the first 3weeks. A recent prospective cohort study by Sinikumpu et al in 2013 found a re-displacement rate of 22% in the conservatively treated group during follow up [4].

Several factors are known to contribute to re-displacement following conservative management. Perfect anatomical reduction of the fracture fragments is amongst the most important factors in preventing re-displacement as reported by Yang et al [14].

The greater initial degree of displacement, the higher the chances of re-displacement. Among the interventional factors, the quality of casting is also important in influencing re-displacement, as is measured by the cast index on conventional anteroposterior and lateral radiographs at the fracture site, proposed by Chess et al. (50). Kamat *et al.* demonstrated that a cast index should be below 0.7 to 0.8, as ratios above this range have been correlated with significant increase in risk of re-displacement [15].

The position of immobilization of the forearm depends on the site of the fracture, proximal third fractures are immobilized with forearm in supination due to the pull of the supinator and biceps muscles. The middle third are immobilized with the forearm in the neutral position, whereas the distal third are immobilized with the forearm in prone position, due to the pull of the pronator quadratus muscle. For optimal results following conservative management, a neutral position of the forearm in the cast is recommended [16], [17], [18].

Paediatric forearm fractures, in particular, have seen an increased rate of surgical treatment despite the lack of comparative studies showing a clear benefit over non-operative treatment [19], [20].

Zionts et al performed a prospective study of older paediatric patients with a mean age of 13.3 years (8 to 15) and observed outcomes of non-operative management after closed reduction. All 25 patients had full range of motion of their wrist and elbow with an average loss of 4° of forearm pronation and 6.8° of supination [21].

Carey et al examined age differences among patients managed with closed reduction. The authors found that patients aged < 10 years with < 30° angulation at the time of reduction could expect minimal angulation and full range of motion at healing. In contrast, patients aged 11 to 15 years were found to have residual angulation with 60% of patients experiencing residual loss of up to 30° of forearm rotation, albeit with no functional loss [22].

Table 1. Acceptable deformity in cases of paediatric both-bone forearm middle-third shaft fractures.

Deformity	*Children <9 years*	*Children ≥9 years*
Angular deformity	< 10–15°	< 8–10°
Rotational deformity	< 45°	< 30°
Shortening	< 10 mm	< 10 mm
Translation	< 100%	< 100%

Information from articles by Price, by Jones and Weiner, and expert opinion published by Mehlman and Wall

Anatomy

Forearm anatomy is very crucial to the peculiarity noted with forearm shaft fractures. Proximally, the radius and ulna have a good soft tissue envelope with abundant muscle cover providing for buffering of forces to prevent fractures, whereas the distal shafts have more of tendinous cover.

The radius is laterally placed and bowed, with a medial border for attachment of the interosseous membrane, which is responsible for transmission of axial load to the ulna. The radial tuberosity is positioned medially & is aligned 180degrees away from the radial styloid with the forearm in supination on the AP view radiograph, thus enabling to assess for any rotational malalignment [23].

The ulna has a proximal projection, the coronoid process; which is oriented at 180degrees from the ulnar styloid on the lateral radiograph. The nutrient vessel to the ulna enters it in its middle third.

The interroseous membrane is attached to both forearm bones and serves transmission of load and provision of axial stability. The interosseous membrane bears attachments of various muscles in the forearm and also bears tensile properties. The interroseous ligament, the central oblique portion, is responsible for about 71% of the longitudinal stability and histologically resembles the ACL and patellar ligament [24].

The periosteum is thick in children and has high osteogenic potential, responsible for the highly agreed-upon conservative management in children [25].

The contour and shape of the bones also change, with the distal radius being ovoid in cross sectional views and cylindrical proximally, this change in shape provides for weaknesses along which fracture lines easily occur.

Most of the growth occurs at the biologically active distal radial and ulnar epiphysis [5], [26], explaining the increased remodeling capacity of the distal shafts, with increased acceptable angles of angulation and displacement.

Most of the diaphysis is hard, cortical bone with poor remodeling potential as compared to the ends [27].

Mechanism of Injury

Fall on an outstretched arm is the most common mechanism of injury, with care-free playground activities for the younger children and active contact sports for the adolescents making them susceptible to skeletal injury [28]. At the point when children fall, they regularly ensure themselves by outstretching the furthest point [29]. Right now, hand is normally pronated during landing and the thenar takes the primary blow against the ground. These prompts quick supination of the pronated lower arm. Right now sweep ingests the most elevated burden and breaks first, contrasted with the ulna [30]. Due to the injury component, there is typically both malalignment and rotational abnormality in lower arm shaft cracks [25]. Malrotation of the lower arm is likely if cracks of the range and ulna are at various degrees of the lower arm [29]. In spite of the angulation, rotational deformation is improbable if the span and ulna break at a similar degree of the lower arm [30].

Direct trauma, such as a blow to the forearm; has also been stated for fractures of both forearm bones. Due to the thick and elastic periosteum, with increased porosity of pediatric bone, plastic deformation does occur on repeated slow longitudinal force causing it to bend. Greenstick fractures also do occur and represent an intermediate between plastic deformation & complete fractures, with some level of cortical continuity.

The injured child presents with pain, swelling, visible deformity and loss of supination and pronation movements [31]. However, plastic deformation and greenstick injuries may be associated with minimal findings.

Examination should also be directed to assess for signs of neurovascular damage, compartment syndrome and presence of any proximal or distal dislocations. The skin envelope must also be carefully examined for any puncture wounds.

Antero-posterior and lateral radiographs of the forearm taken in the neutral position are sufficient to describe the pattern of the fracture and degree of displacement [32].

Classification

The AO classification system is somehow cumbersome and complex, thus it is not commonly used. Classification is based on the location of the fracture, the fracture pattern, the direction of the displacement and the soft tissue cover.

Location of fracture: proximal, middle, distal thirds

Fracture pattern: plastic deformation, greenstick, complete or comminuted.

Displacement: dorsal, volar, ulnar, radial.

Soft tissue cover: open/closed

Monteggia, galeazzi, metaphyseal and epiphyseal fractures are classified separately.

Management

Most diaphyseal forearm fractures are successfully managed by closed reduction with casting [4] [33], [6]. However, the choice of management modality is also dependent on the presence of any vascular injury, compartment syndrome, presence of any fracture dislocations and on the state of the soft tissue envelope.

Factors which influence the choice of the management modality being used are the age of the patient, the type of the fracture and the initial fracture displacement

Remodelling

Remaining bone growth in children reflects great osteogenic potential and remodelling capacity [34]. Remodelling continues even after the fracture has healed until the physes close ([27]).

Due to increased distance from the distal growth plates, midshaft forearm fractures are known to remodel relatively poorly; with a higher incidence of malunion, as compared to the distal shaft fractures [35].

Remodeling capacity has been shown to vary with age, the location of the fracture and the magnitude of the angulation.

Since remodeling capacity decreases with increasing age and more proximal shaft fractures, residual angulation of middle and proximal shaft fractures is more problematic in older children [36], [26].

Unlike remodeling after angulation, malrotation is not corrected by remodeling.

Fracture Reduction

Reduction is usually performed in the emergency department under sedation or general anaesthesia in theatre. The method of closed reduction and casting is guided by common principles: obtaining relaxation/anesthesia, recreating the initial deformity allowing the fracture to unlock, obtaining length with longitudinal traction, and reducing angular/rotational deformity followed by careful cast application.

Traction can be applied using an assistant to horizontally exert a pull on the arm with the fingers being held by finger traps to aid in the traction pull and relaxation of muscles.

For single bone fractures, the reduction manouvre explained in Rockwoods and Wilkins by Blount et al, uses the intact bone as a lever to attain length, thereafter transverse forces are applied to gain satisfactory reduction.

For fractures at same level, there are minimal rotational/torsional forces, thus gentle traction for 5-10 minutes allows the bones to return back to their normal anatomical rotational alignment.

For fractures in the proximal third, the forearm is immobilized in the supine position; for middle third fractures in the neutral position; for the distal third in the prone position.

Challenges to successful fracture reduction do occur, such as interposed soft tissues, torn interosseous membrane, button hole effect of the periosteum.

Casting

Proper moulding of the cast is essential for successful closed management. A snug fit above elbow cast is preferred with the elbow in flexion to minimize distal slippage of the cast.

Generally accepted principles include 3 point moulding of the cast, adequate soft padding, protection of the bony eminences, adequate interosseous mould to maintain the IOM under tension, straight ulnar border to prevent ulna sagging and adequate casting material without excessive weight or heat generation for appropriate cast bone coupling.

The elbow & wrist joints are immobilized and the forearm supported with a cuff and collar or a broad armsling.

Cast Index which is a ratio of the saggital width to the coronal width of the cast at the level of the fracture, should be less than 0.7, to prevent re-displacement of the fracture, as shown by Kamat et al [15]. This measurement is taken from inside of the cast in both views. This helps to maintain the interosseous membrane tension, preventing collapse of fracture fragments.

There is a debate about casting above elbow, with the elbow extended versus flexed; however, from conventional practice, casts are applied above elbow, with the elbow flexed and forearm immobilized in the position based on the level of the fracture.

The position for above elbow casts with the elbow extended gives more stability by natural gravitational pull and weight of the limb to maintain traction, it also tends to prevent re-displacement by minimizing limb usage, however it is an awkward position as reported by walker and Rang et al [37].

Well moulded above elbow casts are kept in place till fractures have healed, usually for a duration of (4-6) weeks as is the norm at KNH.

Acceptable Reduction

No universally fixed agreed consensus exists on the acceptable reduction following closed casting, however, the aim should be to have a cosmetically grossly normal looking forearm with normal or near normal functional range of motion, the lengths of the ulna and radius should be restored to avoid any ulna variance,

Franklin *et al.* stated that successful treatment of pediatric forearm fractures should result in painless and complication-free outcomes with functional pronation - supination [38].

Price et al concluded closed reduction was indicated in patients aged less than 8yrs with fracture angulation of greater than 10 degrees and malrotation greater than 30 degrees [8].

Tarmuzi *et al.* in his retrospective study on 48patients with forearm fractures managed conservatively between the age of (4-12)yrs concluded that up to 1cm of shortening and up to 20 degrees of angulation is acceptable for closed management for children aged under 10yrs, with average union time being 4.6wks [39].

Noonan *et al.* concluded closed reduction was acceptable for children aged less than 9yrs, with angulation up to 15degrees, malrotation of up to 45 degrees and shortening of up to 1cm for midshaft diaphyseal fractures and that once fractures have healed, residual loss of motion of greater than 60 degrees in prosupination axis should be considered an indication for corrective osteotomy [23].

Table 2: Recommended acceptable alignment parameters for diaphyseal pediatric forearm fracture.

Author	Age (yrs)	Angulation (degrees)	Malrotation (degrees)	Displacement/bayonette apposition
Price 2010 (39)	<8yrs	<15 MS,DS; <10 PS	<30	100% displacement
Noonan 1998 (40)	<9yrs	<15	<45	<1cm short
Tarmuzi 2009 (41)	<10yrs	<20		
Qairul 2001 (51)	<12	<20		

MS – midshaft, PS – proximal shaft, DS – distal shaft.

Morrey et al showed that the normal range of motion for pronation is 71 degrees and for supination is 84 degrees, however, most activities of daily living needed up to a total of 100 degrees of rotation, 50 degrees supination and 50 degrees pronation [40].

The remodeling capacity tends to decrease with increasing age and with increasing distance from the growth plate, thus proximal shaft fractures in older adolescents have been showed to have poor remodeling and are associated with higher malunions.

Rotational deformities don't tend to correct, unlike angulation deformities which have relatively better remodeling and functional outcomes.

Once reduction has been done, a well moulded cast is applied and check Xrays done to evaluate the reduction.

Follow up Xrays can be done at 2weeks to check for any re-displacement [7].

The xrays cannot accurately assess rotational deformities for which the CT scans are preferred, however, using the cortical contact and the relationships of the coronoid process of the ulna to the ulna styloid and for the radius the radial tuberosity and the radial styloid, can help in estimating rotational deformity.

Re-displacement after Casting

The most common immediate short term complication of closed management of diaphyseal forearm fractures is loss of reduction, occurring usually within the first 3weeks. Several authors have found rates of re-displacement, ranging from 10% - 50%.

Voto et al in his study on 90patients with forearm fractures, found a rate of 7% re-displacement for conservatively treated forearm shaft fractures, with most of the re-displacement occurring within 2weeks [7].

Sinikumpu et al in his study on 97 patients, found a rate of 21% re-displacement following non-operative management of midshaft forearm fractures [4].

Asadollahi et al in his prospective study on 269 patients in 2015, reported a re-displacement rate of 11% at 2weeks for midshaft forearm fractures managed by closed reduction and casting [41].

Yang et al in his retrospective study on 57patients with forearm fractures managed conservatively, recorded re-displacement in about 22patients, translating to 39% [14].

Bowman et al and Mehlman et al in 2011 in one of the biggest retrospective study on both bone shaft fractures in 282 children managed conservatively, found re-displacement in 144 patients, giving a rate of 51%, with 94% of the re-displacement occurring within 3wks after casting [42].

TABLE 3: Rates of re-displacements by various authors

Author	Re-displacement rate
Voto et al 1990	7%
Sinikumpu et al 2013	21%
Asadollahi et al 2015	11%
Yang et al 2012	39%
Bowman & Mehlman et al	51%

Some of studies have evaluated predictive factors for re-displacement of distal radius fractures (Mani et al. 1993, McLauchlan et al. 2002, Zamzam and Khoshhal 2005, Alemdaroglu et al. 2008), however minimal data is available in helping to predict re-displacement of diaphyseal forearm fractures.

Re-displacement following casting is multifactorial and can be categorized as shown by mazinni and rodriguez et al into; patient related factors, fracture related factors and surgeon related factors [43].

Fracture related factors	Initial displacement, location of the fracture, distance from the physis, isolated distal radius fracture, associated ulna fracture at the same level, obliquity of the fracture
Surgeon related factors	Inadequate initial closed reduction, poor casting technique
Patient related factors	Muscle atrophy, resolution of initial soft tissue swelling while in cast, hand dominance, BMI, gender, age

Anatomical reduction is among the most important and known factors in preventing re-displacement. Asadolahi et al in his study in 2015 on 269 patients with diaphyseal forearm fractures managed conservatively showed that almost anatomical reduction was helpful in preventing re-displacement during the follow-up period and consequentially showed that re-displacement occurred in fractures which were more displaced initially (43). Yang et al had similar findings likewise [14].

Colaris et al in his prospective study on 247patients concluded that the more displaced the initial fragements of the fracture, the higher the risk for re-displacement. Complete fractures significantly increased the risk for displacement, Complete fractures with translation and shortening seem to be more unstable than angulated greenstick fractures with intact periosteum on one side. He found a re-displacement of 27% with mean time of 3weeks [44].

Both bone forearm fractures have higher probability of unsatisfactory anatomical reduction and thereby a higher probability of re-displacement [12].

Among the other important interventional factors, the quality of the cast can also influence re-displacement. Proper casting technique is of paramount importance for maintaining reduction to avoid re-displacement. Fenton et al. concluded that fractures managed conservatively by less experienced surgeons revealed increased rates of re-displacement, due to less technical expertise and skill [45].

Various radiographic indices of the moulded cast have been proposed in equally predicting re-displacement following conservative management.

Cast index as defined by Chess et al in 1994 is calculated by measurements of the cast mould at the fracture site using the anteroposterior and lateral radiographs [46]. Kamat *et al.* demonstrated that a cast index should be below 0.8, as ratios above this range have been correlated with significant increase in risk of redisplacement [15].

Various authors have debated on using an above elbow cast with the elbow flexed or extended. Bochang et al [47] in 2003 advocated the use of the elbow extended position for unstable forearm fractures with no re-displacement in the extended group as incompared to the elbow flexed group which showed a re-displacement of 17.6% at 2weeks post casting, however, Walker and Rang [37] concluded that casting of the fractures with the elbow flexed position was better than the extended position, overlooking the benefits of maintaining unstable fractures in plaster casts with the elbow extended, stating that the extended elbow position was awkward for patients.

There is lack of consensus on the conversion of casting, from above elbow to below elbow at 3weeks. Colaris et al in his study showed no re-displacement in the conversion to below elbow cast group and advocated the conversion of above elbow cast to below elbow cast at 3weeks in childen aged <16yrs.

For patient related factors,
Age is a predictive factor for loss of reduction. Bowman et al showed that children above the age of 10yrs failed closed reduction compared to those below 10yrs of age; using the 10degrees angulation criteria for acceptable reduction [42].

Fractures in the non-dominant arm are at increased risk for re-displacement, which can be explained by less stability of the fracture by poorly developed muscle cover in the non-dominant forearm [44].

The ratio of midshaft forearm fractures for males to females is 3:2, with peaks at (12-14)yrs for males and (10-12)yrs for females; explained by the teenage onset and growth spurt accompanied with increased sporting and field activities; re-displacement is thus more common in these age groups.
De fransesco et al in his retrospective cohort study showed BMI as a risk factor for re-displacement of diaphyseal forearm fractures treated conservatively, with 7.2% re-displacement rate in normal weight children and 44.4% in obese children; he thus recommended closer follow up with a lower threshold for surgical fixation in overweight and obese children [48].

STUDY QUESTION:

What is the incidence of re-displacement and the role of cast index as a predictive factor for re-displacement in diaphyseal forearm fractures in children following closed manipulation and casting in Kenyatta National Hospital.

Study Justification:

Diaphyseal forearm fractures are the 3rd most common paediatric fractures, following supracondylar humeral fractures and distal metaphyseal radial fractures [53].

Most of the diaphyseal forearm fractures are managed conservatively by closed reduction and casting with fairly good outcomes reported in most of the cases. However, re-displacement seems the most common complication after closed reduction, with previous studies reporting high rates of upto 50%.

The re-displacement if not corrected leads to malunion, both cosmetically and in terms of forearm rotation.

No study has so far been done on diaphyseal forearm fractures in children in Kenya, previous studies have focused on distal metaphyseal radial fractures [54].

Availability of data on the incidence and the predictive factors for re-displacement will enable formulation of guidelines in easing management of this type of fractures in the local paediatric population, thus helping choice of surgical patients and reducing any unnecessary visits/expenses.

Study Objectives:

Main objective

To determine frequency of re-displacement of diaphyseal forearm fractures in children treated by closed reduction and casting at Kenyatta National Hospital

Primary objective

- ❖ To determine the prevalence of re-displacement of diaphyseal forearm fractures in children managed by closed reduction and casting at KNH

Secondary Objectives

- ❖ To determine the pattern of closed diaphyseal forearm fractures in children at KNH
- ❖ To correlate cast index and rate of re-displacement for closed diaphyseal forearm fractures in children at KNH
- ❖ To describe the predictive value of patient related factors (age, sex, hand dominance, obesity) to re-displacement of closed diaphyseal forearm fractures in children at KNH
- ❖ To determine the effect of fracture related factors (initial degree of angulation, both bone fracture, initial displacement and shortening) on re-displacement of closed diaphyseal forearm fractures in children at KNH

Methodology:

Study design

Prospective observational study

Study setting

Study was done at orthopaedic clinic, A&E department and paediatric orthopaedic ward at Kenyatta National Hospital (KNH). KNH is the national and largest referral facility in kenya, having the highest number of patients, serving as a true representation of the local population.

Study population:

All children between the ages of (2-13) yrs with consenting legally acceptable representative (LAR) presenting in KNH with closed isolated diaphyseal forearm fractures were considered eligible for enrollment in this study.

Children below 2yrs rarely sustain these types of fractures and children above 16yrs, mostly have closure of the distal physis and thus managed like adults with a different protocol.

Sample size:

To calculate the sample size for this study, we had to estimate the proportion of patients with re-displacement of diaphyseal forearm fractures

$$n = \frac{{Z_{\alpha/2}}^2 p(1-p)}{e^2}$$

Reference: Fleiss, Statistical Methods for Rates and Proportions, formulas 3.18 &3.19

Where;

p = proportion of patients who had re-displacement of diaphyseal forearm fractures (here 30%)

Z_α = Represents the desired level of statistical significance (typically 1.96 for 95% confidence).

e = error margin (5%)

n_0 = Sample size for infinite population (here n_0=362 women)

Since the population here (N) is finite = 60 (number of patients seen at the clinic during a period of 3 months), the adjusted sample size will be calculated as below;

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Required sample size n=52

Inclusion criteria

- Children between the age of (2-13) yrs with closed isolated diaphyseal forearm fractures
- Legally accepted representative (LAR) willingly giving consent for participation of the minor in the study
- Patients with acceptable reduction (as per the guidelines below)
- Availability of health records/xrays

Exclusion criteria:

1. LAR declining consent
2. Fracture dislocations (monteggia and galleazi)
3. Open fractures
4. Fractures with unacceptable reduction after the 2 attempts in the same sitting.
5. Pathological fractures; such as in patients with rickets, osteogenesis imperfecta, etc.
6. Refractures
7. Presence of compartment syndrome
8. Floating elbow

Data Collection:

Consent information document, Consent form, assent information document and assent form were given to parents or guardians and children presenting to KNH for treatment of diaphyseal forearm fractures and those who fulfilled the inclusion criteria. Data collection began once informed consent had been obtained.

The entry point was the orthopaedic clinic. The researcher directly interviewed the patients whose fractures had already been reduced and casted at the casting room at KNH A&E, examined them and studied their radiographs before and after cast application. A follow up radiograph was taken and studied two weeks after cast application since 90% of re-displacements had been shown to occur by then.

Angulation in the saggital and coronal planes was measured on the xrays as well as the percentage translation of the fracture fragments. The angle of angulation was the goniometric measurement of the angle, measured by a protractor, formed by lines drawn in the longitudinal axis of the proximal and distal fragments passing in the middle of the shafts. Sagittal angulation was measured in the Lateral radiograph while coronal angulation was measured on the anteroposterior radiograph.

Acceptable reduction was based on combination of the figures in the table 1 above.

Children less than 9yrs – angulation up to 15degrees, malrotation up to 45 degrees, 100% displacement, shortening up to 1cm.

Children above 9yrs – angulation up to 10degrees, malrotation up to 30degrees, 100% displacement, shortening up to 1cm.

Data was collected using the case report forms (CRF) dispatched by the researcher and his assistant.

Researchers' assistant was an Orthopaedic trauma technician with a diploma from KMTC Nairobi and work experience of over 15yrs in closed fracture management.

Data was collected as below:

Age and sex of the patient

Hand dominance

Weight (kilograms) – measured by weighing using digital weighing scale in kilograms

Height (metres) – measured using a metre rule and tape measure

Mechanism of injury

Date and time of reduction

Pattern of the fracture sustained

Initial displacement.

Displacement after reduction and displacement at 2wks after casting, because 90% of re-displacement following closed reduction had been shown to occur within 2wks following casting.

Data management/analysis

All questionnaires were checked and assessed for completeness before data entry. These questionnaires were stored under lock and key in a cabinet. Data entry was done into a password coded database accessible only to the Data Manager, Data Clerk and the Principal Investigator. Once data entry was complete, the entered data was assessed for accuracy and identified entry errors corrected.

Exploratory data was thereafter analysed to identify any irregularities and extreme values. For description of the study population, fractures and redisplacement, categorical variables were summarized by means of counts and percentages using frequency tables while continuous variables were summarized by use of measures of central tendency and dispersion (mean, standard deviation, median, minimum, maximum, range, IQR).

Determination of factors associated with redisplacement, chi-squared tests were applied for categorical variables and analysis of variance (ANOVA) tests were done for continous variables. Logistic regression was thereafter applied to determine independent factors associated with redisplacement.

Presentation of results was by use of tables, graphs, charts and text narratives.

Dissemination plan of findings

The findings of this research in the form of dissertation would be handed over to department of orthopaedic surgery at UoN and ERC KNH to help in appropriate policy making and formulation of standard operation protocol for management of such types of fractures. They will also be available for future reference at the UoN library.

Utility of results

The results from this study will help in formulation of standard operation protocol (SOP) for management of such types of fractures at KNH, by providing a base of reference in management of such type of fractures.

RESULTS

Fifty-two patients were recruited in this study. These were 40 males and 12 females with a male female ration of 3.5:1 (Figure 1). The mean age of the participants was 9±2years. Most (80.8%) of the participants were right hand dominant.

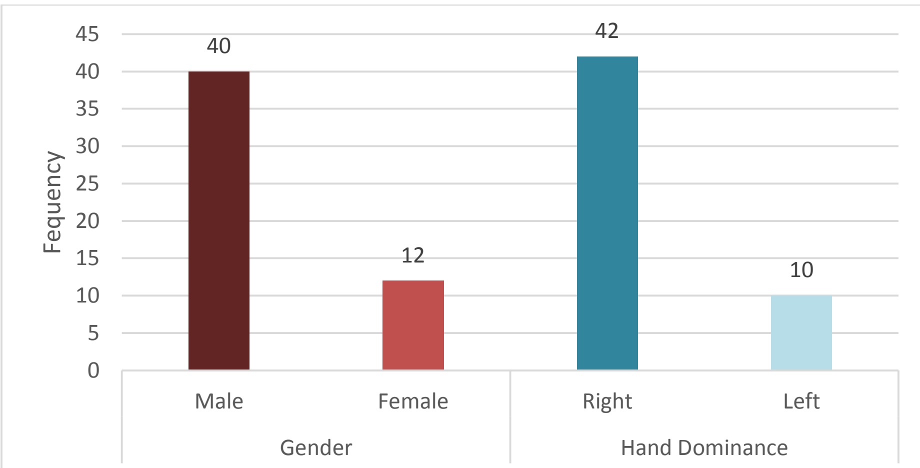

Figure 1: Distribution of gender and Hand dominance

Rates of Re-displacement

At two weeks post casting time, the redisplacement rate of forearm fractures was 29% (N=15) [Figure 2]. These re-displacements comprised of sagittal angulation (60%), coronal plane angulation (20%), overlap of both the radius and ulna 4%, overlap of the radius 2%. Most of the redisplaced fractures were in the distal $^1/_3$ segment of the bones (P=0.038). The other features of the re-displaced forearm bones are summarized in table 4 below.

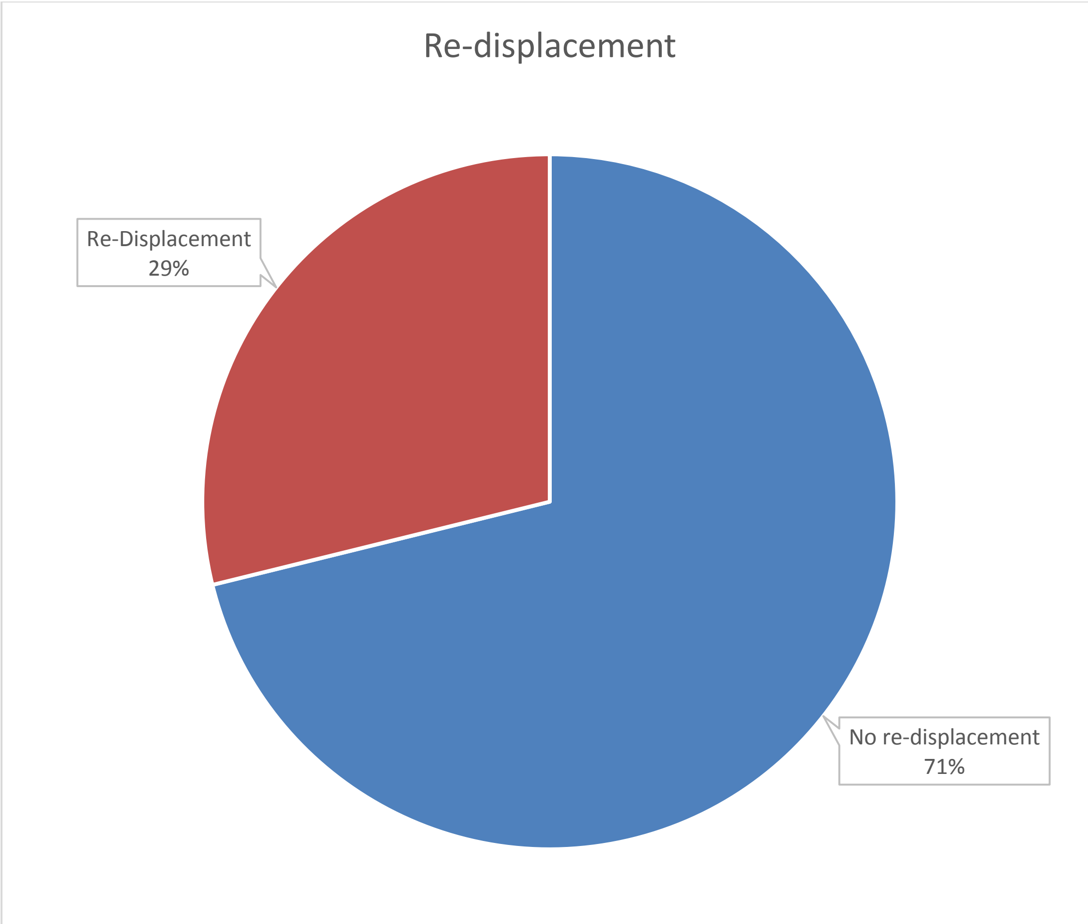

Figure 2: A chart showing the redisplacement rate of paediatric forearm fractures

Table 4: Table summarizing the features of the individuals with forearm fractures

		Re-displacement				p-value
		No re-displacement		Re-Displacement		
		n	%	n	%	
Gender	Male	29	72.5	11	27.5	0.696
	Female	8	66.7	4	33.3	
Hand Dominance	Right	32	76.2	10	23.8	0.100
	Left	5	50.0	5	50.0	
Source of arm injury	Fell while playing	33	75.0	11	25.0	0.083
	Fell from height	3	42.9	4	57.1.	
Involved bones	Both	37	71.2	15	28.8	-
	Radius only	0	.0	0	.0	
	Ulna Only	0	0	0	0	
Fractures at the same level in both the bones	Yes	37	71.2	15	28.8	-
	No	0	0	0	.0	
Level of the ulna fracture	Proximal third	1	25.0	3	75.0	0.038
	Middle third	21	84.0	4	16.0	
	Distal third	15	65.2	8	34.8	
Level of the radial fracture	Proximal third	3	60.0	2	40.0	0.576
	Middle third	18	78.3	5	21.7	
	Distal third	16	66.7	8	33.3	
Fracture pattern for ulna	Greenstick	7	87.5	1	12.5	0.267
	Complete	30	68.2	14	31.8	
Fracture pattern for radius	Greenstick	6	75.0	2	25.0	0.766
	Complete	30	69.8	13	30.2	
Cast index		0.90		1.5		0.05

The most common cause of the injury was a fall when playing (N=44), the rest fell from a height (Table 4).

Pattern of closed forearm diaphyseal fractures

The forearm fractures involved both bones at the same level in all of the cases (Table 4). Most fractures were complete (69%) and involved the middle segment (70%) of the bones. The other features of these fractures are summarized in table 4.

Correlation between redisplacement and cast index

The mean cast index ratio was 1.1±0.1. The cast index of 0.7 - 0.81 was observed in 70% of the cases. The rest of the cases had a cast index >0.81. Data was recorded into these two categories, those with cast index of <0.81 and those with index of >0.81. Most (85%) of the patients who had redisplacements had a cast index of > 0.81 (Table 5). The mean cast index of the redisplaced fractures was 1.5±1.8. While the mean index of the non redisplaced fractures was 0.9±0.1. The difference between them was significant (P=0.05) [Table 5].

Predictive value of patient related factors (age, sex, hand dominance, obesity) to redisplacement

Taller, older, heavier patients redisplaced their fractures compared to their counterparts. The mean age of the patients with redisplaced and non redisplaced fractures was 10.2±1.6yrs and 8±2.3yrs respectively (P=0.001) [Table 5]. The mean weight for the patients with redisplacment was 15.3±3.9kg. The mean weight for the patients with without redisplacment was 13.0±2.8kg (Table 5). Using independent sample T test, there was no significance in the rates of displacement as a factor of patients' factors such as BMI and hand dominance (Tables 5).

Table 5: Patient features in fracture redisplacement

		N	Mean	SD	p-value
Age (years)	No re-displacement	37	8	2.3	0.001
	Re-Displacement	15	10.2	1.6	
Weight (kg)	No re-displacement	36	13.0	2.8	0.026
	Re-Displacement	15	15.3	3.9	
Height (Meters)	No re-displacement	36	0.7	0.14	0.015
	Re-Displacement	15	.9022	0.11	
Body Mass Index	No re-displacement	36	21.705	7.2364	0.150
	Re-Displacement	15	18.8	3.6	
Number of days after Injury	No re-displacement	37	1.75	1.51	0.475
	Re-Displacement	15	1.4	0.5	
Pre-casting Angulation in sagittal plane for radius (degrees)	No re-displacement	37	4.2	2.7	0.148
	Re-Displacement	15	5.5	2.9	
Pre-casting Cortical translation for ulna	No re-displacement	37	30.1	39.4	0.002
	Re-Displacement	15	69.6	36	
Pre-casting Cortical translation for radius	No re-displacement	37	14.1	19.8	0.002
	Re-Displacement	15	33.3	18.5	
Pre-casting Overlap for ulna	No re-displacement	37	2.838	14.8	0.518
	Re-Displacement	15	.333	1.29	
Pre-casting Overlap for radius	No re-displacement	37	.270	1.6440	0.530
	Re-Displacement	15	.000	.0000	
Diameter of cast in saggital plane (Cm)	No re-displacement	37	3.665	.2983	0.007
	Re-Displacement	15	4.587	1.9584	
Diameter of cast in coronal plane (Cm)	No re-displacement	37	3.989	.4926	0.171
	Re-Displacement	15	4.333	1.3119	
Cast index ratio	No re-displacement	37	0.918	0.1128	0.05
	Re-Displacement	15	1.504	1.8059	

Fracture features versus redisplacement

The overall fracture parameters before and after casting are summarized in tables 5 and 6 (Figure 3). Most redisplaced fractures were in the distal segment of the bones. The pattern of fracture, as well as the involvement of both bones did not affect the rate of displacement of the fractures (Table 5). Higher precasting translation of both bones predicted redisplacement (Table 5).

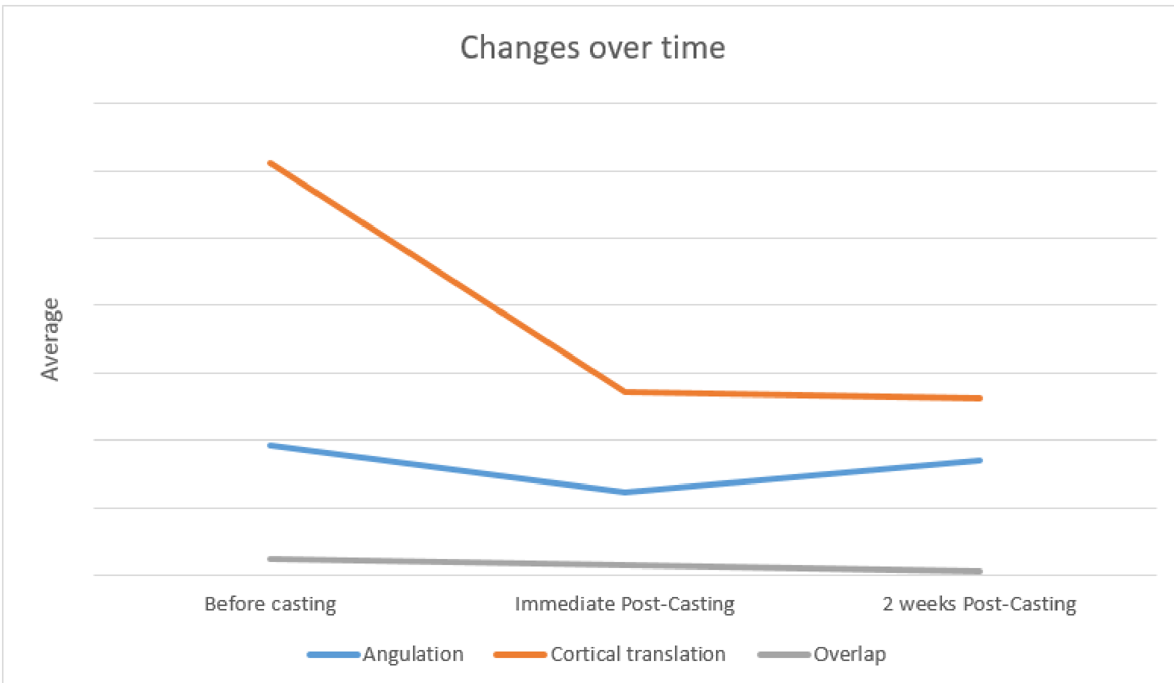

Figure 3: Changes in the fracture deformity at the point of injury, immediate post casting and at 2 weeks post casting.

Table 6: Fracture parameters before and after casting

	Before casting		Immediate Post-Casting		2 weeks Post-Casting	
Measurement	Mean	SD	Mean	SD	Mean	SD
Angulation in coronal plane for radius (degrees)	15.9	7.6	9.6	8.6	11.8	7.6
Angulation in coronal plane for ulna (degrees)	10.7	5.4	6.3	4.6	9.6	4.3
Angulation in sagittal plane for radius (degrees)	7.4	3.9	4.3	4.0	6.6	4.6
Angulation in saggital plane for ulna (degrees)	4.6	2.8	4.4	3.7	6.1	3.7
Cortical translation for radius	41.5	42.2	13.4	20.2	15.9	23.1
Cortical translation for ulna	19.7	21.2	13.8	19.3	10.4	15.5
Overlap for radius	2.1	12.5	1.0	6.9	.3	2.1
Overlap for ulna	.2	1.4	.4	2.8	.2	1.1

DISCUSSION

The main treatment of closed diaphyseal forearm fractures remains closed manipulation and casting for children. The main challenge of this method remains maintenance of the reduction, with re-displacement being the most common complication. Re-displacement of the fracture leads to cosmetically poor looking forearms as well as in loss of function, especially in the pronation-supination rotational movement of the forearm.

This study found a total re-displacement rate of 28.8% which is comparable with previous studies done globally.

Sinikumpu et al, in his study on 97 patients, found a rate of 21% re-displacement following non-operative management of midshaft forearm fractures [4]. Asadollahi et al, in his prospective study on 269 patients in 2015 reported a re-displacement rate of 11% at 2weeks for midshaft forearm fractures managed by closed reduction and casting [41]. Yang et al, in his retrospective study on 57patients with forearm fractures managed conservatively, recorded re-displacement in about 22patients, translating to 39% [14].

This study took into consideration redisplacement of diaphyseal forearm fractures, proximal shaft, midshaft and distal shaft also, thus accounting for the slightly higher redisplacement rate, since the distal diaphyseal forearms have higher redisplacement rates as shown by previous studies.

Risk factors for Redisplacement

Re-displacement following casting is multifactorial and can be categorized as shown by Mazinni and Rodriguez et al into; patient related factors, fracture related factors and surgeon related factors [43].

In this study, the following factors were evaluated as likely to contribute to redisplacement:

Age of the patient
Sex of the patient
Height and weight of the patient
Mechanism of injury

Duration after injury to seek medical attention

Hand dominance

Level of the fracture

Pattern of the fracture

Initial displacement

Cast index

Age of the patient

The mean age for the study population was 9yrs. The mean age of the patients with redisplaced and non redisplaced fractures was 10.2±1.6yrs and 8±2.3yrs respectively (P=0.001). Redisplacement was observed more in the older children with a mean age of 10.2yrs. Bowman et al showed that children above the age of 10yrs failed closed reduction as compared to those below 10yrs of age; using the 10degrees angulation criteria for acceptable reduction [42]. This finding was similar in my study with statistical significance.

Height and weight of the patient

Redisplacement was seen more in the taller and heavier patients as compared to shorter and thinner patients. The mean height in the redisplaced group was 0.92Metres and the mean weight in the redisplaced group was 15.3kg. BMI was however not found to be a significant risk factor in the redisplacement of diaphyseal forearm fractures. De Fransesco et al in his retrospective cohort study showed 7.2% re-displacement rate in normal weight children and 44.4% in obese children; he thus recommended closer follow up with a lower threshold for surgical fixation in overweight and obese children [48].

Cast Index

The cast mould is an important interventional factor in influencing re-displacement. Proper casting technique is of paramount importance for maintaining reduction to avoid re-displacement. Cast index as defined by Chess et al in 1994 is calculated by measurements of the cast mould at the fracture site using the anteroposterior and lateral radiographs [46]. Kamat *et al.* demonstrated that

a cast index should be below 0.8, as ratios above this range have been correlated with significant increase in risk of redisplacement [15].
Cast index of above 0.9 was associated with statistically significant redisplacement in this study, this correlates to the previous studies done by Kamat et al and chess et al, whereby higher cast index ratios are surgeon related modifiable predictive factors for redisplacement of diaphyseal forearm fractures.

Initial fracture displacement

In this study, I did not find pattern of fracture, completeness of the fractures as well as the involvement of both bones affecting the rate of redisplacement of the fractures. These findings were similar to those of Voto et al [7]. I, however, found that higher precasting translation of both bones predicted redisplacement. Majority of the re-displaced fractures were in the distal diaphyseal region as compared to midshaft, while most of the fractures were actually complete midshaft diaphyseal fractures.

Asadolahi et al in his study on 269 patients with diaphyseal forearm fractures managed conservatively showed anatomical reduction is protective against re-displacement during follow-up and further showed that re-displacement occurred more in fractures that were displaced more initially (43). Similar findings were also reported by yang et al [14].

Colaris et al in his prospective study on 247patients concluded that initial displacement and completeness of the fractures significantly increased the risk for displacement, Complete fractures with translation and shortening seem to be more unstable than angulated greenstick fractures with intact periosteum on one side. He found a re-displacement of 27% with mean time of 3weeks [44].
Both bone forearm fractures have higher probability of unsatisfactory anatomical reduction and thereby a higher probability of re-displacement [12].
These findings could be attributed to the lower number of patients in this study, with recommendations for doing a much bigger study to evaluate the fracture characteristics with redisplacement of diaphyseal forearm fractures.

Sex and hand dominance

These were not found to be statistically significant in this study. However, previous studies have shown higher redisplacement rates in the males due to the higher play outdoor activities in the young males. Also studies have shown increased rates of redisplacements for fractures in the non-dominant hands, possibly owing to the poorly developed muscle cover, thereby increasing chances of redisplacement after closed reduction and casting, as shown by colaris et al [44].

Mechanism of Injury and Number of days after injury

44patients sustained injury following a fall on a level ground during play, of which 25% redisplaced. 7 patients had injury following a fall from a height, signifying higher energy injury with more redisplacement rate of 57%. This was however not found to be of any statistical significance. Most of the redisplaced fractures presented at 1.4days after the injury, while most of the non redisplaced fractures presented at 1.75days following injury. Thus most of them presented within 1-2 days following the injury. There was no statistical significance relating the duration of time after injury to redisplacement.

CONCLUSION

Most of the diaphyseal forearm fractures were along the midshaft segment and were complete fractures, followed by greenstick fractures. The total rate for redisplacement was 28.8% in this study.

Factors found to be significant contributors towards re-displacement of diaphyseal forearm fractures in children included: age of the patient, height of the patient, weight of the patient, quality of the plaster mould for immobilization and initial translation of the radius and ulna.

Time from injury to casting, mechanism of injury, sex of patient, hand dominance and initial angulation of the fracture were not found to be significant risk factors associated with predicting redisplacement of diaphyseal forearm fractures managed conservatively in children.

Recommendations:

The need for immediate post reduction radiographs is necessary, to be able to get an anatomical reduction as possible. Follow up radiographs at 2weeks help to check for any possible re-displacement which may occur during conservative management, thus optimizing timely intervention and utilization of other treatment options, in order to prevent malunion

A larger multicenter study to be carried out, with larger numbers so as to give a better representation of the entire population

A similar study should also be done but with CT scans included as an adjunctive imaging modality, to enable assessment of malrotation in diaphyseal forearm fractures.

Ethical considerations:

The study was approved in writing by the university of Nairobi, department of Orthopaedic surgery and Kenyatta National Hospital Ethics Research Committee following submission of the proposal, prior to conducting any activity pertaining to this study.

All children were given written informed consent forms after explaination of the purpose, risks and benefits of this study, participation was on a voluntary basis at their own free-will. The parents/guardians were given consent forms to freely and willingly allow for participation of their children into the study, likewise the minors were given assent forms to fill after being explained the content of the assent forms, so that the minors would be included into the study based on their own freewill voluntarily.

For patients with initial unacceptable reduction, they were referred to the orthopaedic resident for further management and possible fixation, after being notified by the researcher or his assistant.

Patients privacy was maintained and NO information was revealed to anyone whosoever.

All data collected was handed over to the department of Orthopaedic surgery and KNH for appropriate policy making.

Study Limitations:

Data was collected from 1 centre only, KNH.

Difficulty obtaining consent from street children brought in by good samaritans

Closed reduction and casting was done by various plaster technicians and orthopaedic residents, resulting in varying casting techniques and qualities of moulds.

Malrotation was not assessed, since conventional xrays do not accurately quantify the extents of malrotation.

References

1. P, S. P. (2005). State-of-the-art treatment of forearm shaft fractures. Injury, 36(Suppl 1), 25-34.
2. Naranje S M, E. R. (2016). Epidemiology of pediatric fractures presenting to emergency departments in the United States. J Pediatr Orthop, 36, 45-48.
3. Mäyränpää M K, M. O. (2010). Decreasing incidence and changing pattern of childhood fractures: a population-based study. J Bone Miner Res.
4. Sinikumpu JJ, L. A. (2013). Outcomes of children's both-bone diaphyseal forearm fractures after invasive and non-invasive treatment. Injury, 44, 431-436.
5. Ogden JA, B. J. (1981). Radiology of postnatal skeletal development. IV.Disal radius and ulna. Skeletal Radiol, 6(4), 255-266.
6. A, K. (2001). Biomechanics of pronation and supination of the forearm. Hand Clin, 17, 111-112.
7. Alemdaroglu K B, I. S. (2008). Risk factors in redisplacement of distal radial fractures in children. J Bone Joint Surg Am, 90, 1224-1230.
8. Armstrong PF, J. V. (2003). Fractures of the forearm, wrist, and hand. In G. N. (eds), Skeletal Trauma in Children (pp. 166-255). Philadelphia: Saunders Elsevier Science.
9. Bochang C, J. Y. (2005). Immobilisation of forearm fractures in children: exended versus flexed elbow. J Bone Joint Surg [Br], 87(B), 994-996.
10. Bowman E N, M. C. (2011). Nonoperative treatment of bothbone forearm shaft fractures in children: predictors of early radiographic failure. J Pediatr Orthop, 31, 23-32.
11. Carey PJ, A. P. (1992). Both-bone forearm fractures in children. Orthopedics, 15, 1015-1019.
12. Chess D G, H. J. (1994). Short arm plaster cast for distal pediatric forearm fractures. J Pediatr Orthop, 14, 211-213.
13. Colaris J W, A. J. (2013). Risk factors for the displacement of fractures of both bones of the forearm in children. Bone Joint J, 95, 689-693.
14. CT, P. (2010). Acceptable alignment of forearm fractures in children: open reduction indications. J Pediatr Orthop, 30, 82-84.
15. DeFrancesco CJ1, R. B. (2017). Obesity Increases Risk of Loss of Reduction after Casting for Diaphyseal Fractures of the Radius and Ulna in Children: An Observational Cohort Study. J Orthop Trauma.

16. Eismann EA, L. K. (2013). Clinical research fails to support more aggressive management of pediatric upper extremity fractures. J Bone Joint Surg [Am], 95, 1345-1350.

17. EJ, M. C. (2006). Injuries to the shafts of the radius and ulna. In B. J. Wilkins', Fractures in Children (pp. 399-441). Philadelphia: Lippincott Williams & Wilkins.

18. Fenton P, N. P. (2012). Factors in redisplacement of paediatric distal radius fractures. J Pediatr Orthop B, 21, 127-130.

19. Franklin CC, R. J. (2012). Evidence-based medicine: management of pediatric forearm fractures. J Pediatr Orthop, 30, 131-134.

20. Fuller DJ, M. C. (1982). Malunited fractures of the forearm in children. J Bone Joint Surg Br, 64(3), 364-367.

21. Helenius I, L. T. (2009). Operative treatment of fractures in children is increasing. A population-based study from Finland. J Bone Joint Surg [Am], 91(A), 2612-2616.

22. JV, S. (2005). Musculoskeletal injuries in the pediatric and adolescent athlete. Curr Sports Med Rep, 4(6), 329-334.

23. Kamat AS, P. N. (2012). Redefining the cast index: the optimum technique to reduce redisplacement in pediatric distal forearm fractures. J Pediatr Orthop, 32, 787-791.

24. Kay S, S. C. (1986). Both-bone midshaft forearm fractures in children. J Pediatr Orthop, 6(3), 306-310.

25. KE, W. (2005). Principles of fracture remodeling in children. Injury, 36(Suppl 1), 3-11.

26. KE, W. (2005). Principles of fracture remodeling in children. Injury, 36(Suppl 1), 3-11.

27. LG, S. C. (1990). Clinical predictors of forearm fracture in children. Arch Emerg Med, 7(3), 196-199.

28. LM, B. C. (2003). Childhood fractures in Bergen, Norway: identifyinghigh-risk groups and activities. J Pediatr Orthop, 23(5), 629-634.

29. Mani G V, H. P. (1993). Translation of the radius as a predictor of outcome in distal radial fractures of children. J Bone Joint Surg Br, 75, 808-811.

30. Mazzini JP, R. J. (2010). Paediatric forearm and distal radius fractures risk factors and redisplacement:The role of casting indices. Int orthop, 34(3), 407-412.

31. Moore K, D. A. (2006). Clinically oriented anatomy. . Baltimore, MD: Lippincott Williams & Wilkins.

32. Morrey BF, A. L. (1981). A biomechanical study of normal functional elbow motion. J Bone Joint Surg Am., 63(6), 872-877.

33. Nagy L, J. L. (2008). Correction of forearm malunion guided by the preoperative complaint. Clin Orthop Relat Res, 466, 1419-1428.

34. Noonan KJ, P. C. (1998). Forearm and distal radius fractures in children. J Am AcadOrthop Surg, 6, 146-156.
35. Pfaeffle HJ, T. M. (1996). Tensile properties of the interosseous membrane of the human forearm. J Orthop Res, 14(5), 842-845.
36. Price C T, K. D. (2006). Osteotomy for malunited forearm shaft fractures in children. J Pediatr Orthop, 26, 193-196.
37. Qairul IH, K. B. (2001). Early remodeling in children's forearm fractures. Med J Malaysia, 56, 34-37.
38. Richard MJ, R. D. (2007). Richard MJ, Ruch DS & Aldridge III JM. Hand Clin, 23(2), 235-243.
39. Shadi Asadollahi, M. p. (2017). Predictive factors for re-displacement in diaphyseal forearm fractures in children - role of radiographic indices. Acta Orthopaedica, 88(1), 101-108.
40. Sinikumpu J J, S. W. (2015). The shaft fractures of the radius and ulna in children: current concepts. J Pediatr Orthop B, 24, 200-206.
41. ST, H. M. (2006). Forearm fractures in children and adolescents: a practical approach. Hand Clin, 22(1), 55-67.
42. Tarmuzi NA, A. S. (2009). Paediatric forearm fractures: functional outcome of conservative treatment. Bratisl Lek Listy, 110, 568-568.
43. Tubbs R S, O. J. (2007). The oblique cord of the forearm in man. Clinical Anatomy, 20, 411-415.
44. Van Geenen R C, B. P. (1993). Outcome after corrective osteotomy for malunited fractures of the forearm sustained in childhood. J Bone Joint Surg Br, 89, 808-811.
45. Vittas D, L. E.-P. (1991). Angular remodeling of midshaft forearm fractures in children. Clin Orthop Relat Res, 265, 261-264.
46. Vittas D, L. E.-P. (1991). Angular remodeling of midshaft forearm fractures in children. Clin Orthop Relat Res, 265, 261-264.
47. Vopat M L, K. P. (2014). Treatment of diaphyseal forearm fractures in children. Orthop Rev. Pavia, 6, 5325.
48. Voto S J, W. D. (1990). Redisplacement after closed reduction of forearm fractures in children. J Pediatr Orthop, 10, 79-84.
49. Walker JL, R. M. (1991). Forearm fractures in children: cast treatment with the elbow extended. J Bone Joint Surg [Br], 73(B), 299-301.
50. Yang J J, C. J. (2012). Redisplacement of diaphyseal fractures of the forearm after closed reduction in children: a retrospective analysis of risk factors. J Orthop Trauma, 26, 110-116.

51. Zamzam M M, K. K. (2005). Displaced fracture of the distal radius in children: factors responsible for redisplacement after closed reduction. J Bone Joint Surg Br, 87, 841-843.

52. Zionts LE, Z. C. (2005). Closed treatment of displaced diaphyseal both-bone forearm fractures in older children and adolescents. J Pediatr Orthop, 25, 507-512.

53. Cheng, J.C. (1999). A 10-year study of the changes in the pattern and treatment of 6,493 fractures. J Pediatr Orthop, 19(3): p. 344-50.

54. KD O, Atinga'J. (2010). Redisplacement rates after reduction and cast immobilization of isolated distal radial fractures." Annals of African Surgery. 5(1):25-27

APPENDICES

APPENDIX 1: CONSENT INFORMATION FORM FOR PARENTS AND GUARDIANS

Title of the study: Redisplacement of diaphyseal forearm fractures Treated by Cast Immobilization

Principal investigator: Dr. Arif Admani

Introduction

This study seeks to find out the incidence of re-displacement and factors influencing redisplacement (bone slipping out of its normal healing position) of broken forearm in children. The study will help health care givers find a better way of treating the broken bones or prevent the bones from slipping out of its position early.

What are you required to do?

You will help your child answer a few questions about his/her age and how he/she got injured. The doctor (principal researcher or research assistants) will look at your child's injured forearm and their X-rays before and after plaster cast application. You will bring your child back to the hospital for follow up to assess healing progress.

Risk

This study will not harm your child in any way.

Benefit

This study will help doctors in future to make early decisions on other treatment methods if they can predict that the bone will slip out of its position.

Confidentiality

No information that you give us will be shared with other people. All that you tell us will be kept as a secret and only used to answer the questions of this study.

Participation

Your participation in this study is your own choice. Refusal to participate will not be punished. You may discontinue participation at any time without any penalty.

THE END

APPENDIX 2: CONSENT FORM FOR PARENTS/GUARDIANS

Parent/guardian

I have accurately read out the information sheet to the potential participant who is a minor and to the best of my ability made sure the minor understood. I confirm the minor has given assent freely and understands that I have to sign a consent form. I confirm that the child has not been coerced into giving consent.

Name of parent/guardian ________________________________

Signature of parent/guardian________________________________

Date___________________________________

Name of researcher___________________________________

Signature of researcher_________________________________

Date_____________________________

If during the course of this you have any questions concerning this research you should contact:

Dr. Arif Admani

Mobile 0710584111 or

Chairman, UON/Kenyatta National Hospital ethics and Research committee on Tel 020-2726300 Ext 44355

Incase of unacceptable alignment, the child will be referred to the sitting orthopaedic resident at KNH A&E for admission to the ward and possible surgical intervention.

APPENDIX 3: HATI YA MAELEZO YA RIDHAA KWA WAZAZI NA WALEZI

Mkuu wa uchunguzi: Dr. Arif Admani

Utangulizi

Utafiti huu unalenga kujua mvujiko wa mkono na sababu zinazofanya mfupa wa mkono kuwachana tena, baada ya kuvutwa na kufungwa kwa plasta. Utafiti huu utawasaidia madaktari kujua jinsi bora ya kutibu mvunjiko wa mfupa wa mkono ilikuzuia kuwachana kwa mvunjiko huo baada ya kutibiwa.

Je, unachotakiwa kujua ni nini?

Mtoto wako ataulizwa maswali machache kuhusu umri wake na jinsi alivyoumia. Mchunguzi mkuu au wasaidizi wake watauangalia mkono pamoja na kutazama picha za 'Xray' kabla ,na baada ya kufungwa kwa plasta.

Je, kuna madhara yoyote kwa mtoto?

Utafiti huu hauna madhara au hatari yoyote kwa mtoto wako.

Manufaa ya utafiti

Utafiti huu utawawezesha madaktari kujua mvunjiko wa mfupa ambao utawachana baada ya kufungwa kwa plasta.Umaarifa utakaotokana na utafiti huu utawawezesha madaktari kutafuta njia badala ya kutibu mivunjiko hiyo.

Usiri

Maelezo tutakayopata kwako au kwa mtoto wako yatakuwa ya siri na yatatumiwa kwa ajili ya utafiti huu pekee.

Kushiriki

Kushiriki kwako kwa utafiti huu ni kwa hiari yako. Hakuna kulazimishwa. Una uhuru wa kutoshiriki utafiti wakati wowote bila kuathibiwa.

MWISHO

APPENDIX 4: FOMU YA IDHINI KWA WAZAZI NA WALEZI

Nimemsomea mtoto maelezo kama yalivyo kwenye hati ya ridhaa kadiri ya uwezo wangu.Nimehakikisha ya kwamba mtoto ameelewa.

Nimehakikisha ya kwamba mtoto amekubali bila kulazimishwa.Naelewa ya kwamba lazima nitie saini ya kukubali.

Jina la mzazi/mlezi…………………………………………….

Saini ya mzazi/mlezi…………………………………………..

Tarehe………………………………………………………….

Jina la mtafiti………………………………………………….

Saini ya mtafiti………………………………………………..

Tarehe…………………………………………………………

Iwapo ungependa kuuliza maswali au ufafanuzi zaidi utafiti unapoendelea,wasiliana nasi kwa anwani ifuatayo:

Dr. Arif Admani

Simu 0710584111 au

Mwenyekiti, Idara ya maadili na utafiti ya hospitali kuu ya Kenyatta (UON/Kenyatta National Hospital ethics and Research committee) kwa simu 020-2726300 Ext 44355.

Iwapo kurekebisha kwa mifupa haikuwezekana, mgonjwa atatumwa kwa daktari wa mifupa hapo KNH A&E ili waweze kuamua kuhusu kulazwa kwa upasuaji kwa kurekebisha mifupa.

APPENDIX 5: ASSENT INFORMATION DOCUMENT FOR MINORS

Title of the study: Redisplacement of diaphyseal forearm fractures Treated by Cast Immobilization

Principal investigator: Dr. Arif Admani

Introduction

This study seeks to find out the factors influencing redisplacement and its incidence (bone slipping out of its normal healing position) of broken forearm bones. The study will help health care givers such as doctors find a better way of treating the broken bone or prevent the bone from slipping out of its position before it heals.

What are you required to do?

You will answer a few questions about your age and how you got injured. The doctor(principal researcher or research assistants) will look at your injured forearm and your X-rays before and after plaster cast application. Your parent/guardian will bring you back to the hospital to assess healing progress.

Risk

This study will not harm you in any way.

Benefit

This study will help doctors in future to make early decisions on other treatment methods if they can predict that the bone will slip out of its position.

Confidentiality

No information that you give us will be shared with other people. All that you tell us will be kept as a secret and only used to answer the questions of this study.

Participation

Your participation in this study is your own choice. Refusal to participate will not be punished. You may stop participation at any time without any penalty.

THE END

APPENDIX 6: ASSENT FORM FOR MINORS

Parent/guardian

I have fully read the information sheet to the best of my ability. I confirm that I have understood that I have to sign an assent form. I confirm that I have not been forced into giving assent.

Name of minor ---

Signature of minor ---

Date ---

Name of researcher --

Signature of researcher ---

Date --

If during the course of this you have any questions concerning this research you should contact:

Dr. Arif Admani

Mobile 0710584111 or

Chairman, UON/Kenyatta National Hospital ethics and Research committee on Tel 020-2726300 Ext 44355.

APPENDIX 7: HATI YA MAELEZO YA IDHINI KWA WATOTO

Mkuu wa uchunguzi: Dr. Arif Admani

Utangulizi

Utafiti huu unataka kujua kuhusu kuvunjika kwa mkono, kiwango cha idadi yake na sababu zinazosababisha mfupa wa mkono kuwachana tena baada ya kuvutwa na kufungwa kwa plasta.Utafiti huu utawasaidia madaktari kujua vile watatibu kuvunjika kwa mfupa vizuri zaidi.Pia madaktari wataweza kuzuia kuwachana kwa mfupa baada ya kutibiwa.

Je,unachotakiwa kujua ni nini?

Utaulizwa maswali machache kuhusu umri wako,jinsia yako na vile ulivyoumia.Mchunguzi mkuu au wasaidizi wake watauangalia mkono wako uliovunjika pamoja na kutazama picha za ‘Xray’kabla ya,na baada ya kufungwa kwa plasta.

Je,kuna madhara yoyote kwa mtoto?

Utafiti huu hauna madhara au hatari yoyote.

Manufaa ya utafiti

Utafiti huu utawawezesha madaktari kujua mvunjiko wa mfupa ambao utawachana baada ya kufungwa kwa plasta.Umaarifa utakaotokana na utafiti huu utawawezesha madaktari kutafuta njia nyingine ya kutibu mivunjiko hiyo.

Usiri

Maelezo tutakayopata kwako yatakuwa ya siri na yatatumiwa kwa ajili ya utafiti huu pekee.

Kushiriki

Kushiriki kwako kwa utafiti huu ni kwa hiari yako.Hakuna kulazimishwa.Una uhuru wa kutoshiriki utafiti wakati wowote bila kuathibiwa.

MWISHO

APPENDIX 8: FOMU YA IDHINI KWA WATOTO

Mimi nimesoma maelezo kama yalivyo kwenye hati ya idhini kwa uwezo wangu.Nimeelewa maelezo hayo vizuri.

Mimi nimekubali bila kulazimishwa.Naelewa ya kwamba lazima nitie saini ya kukubali.

Jina la mtoto…………………………………………….

Saini ya mtoto…………………………………………..

Tarehe………………………………………………………….

Jina la mtafiti………………………………………………….

Saini ya mtafiti………………………………………………..

Tarehe…………………………………………………………

Iwapo ungependa kuuliza maswali au ufafanuzi zaidi utafiti unapoendelea,wasiliana nasi kwa anwani ifuatayo:

Dr. Arif Admani

Simu 0710584111 au

Mwenyekiti,Idara ya maadili na utafiti ya hospitali kuu ya Kenyatta(UON/Kenyatta National Hospital ethics and Research committee) kwa simu 020-2726300 Ext 44355.

APPENDIX 9: CASE REPORT FORM

Please fill the blanks or tick the appropriate box where applicable

X-ray films will be required for questions 3 to 12. The investigators will help you through questions 3 to 12.

Patient ID (OP/IP no.) ……….Age (years)…………… Date……………

Gender (M/F) ……….......... Hand Dominance …………………

Weight (kg) ……………… Height (metres)………………….

1. When did you sustain injury to your forearm? (Write number of days)

……………………………………………………………………………………

2. How did you injure your forearm?

- Fell while playing
- Road traffic accident
- Fell from height
- Assaulted
- Other

TO BE ANSWERED BY RESEARCHER (3 – 12)

3. Did fractures involve both the forearm bones?

- Yes
- No

4. Were the fractures at the same level in both the bones?

- Yes
- No

5. What is the level of the ulna fracture?

- Proximal third
- Middle third
- Distal third

6. What is the level of the radial fracture?

   - Proximal third
   - Middle third
   - Distal third

7. What is the fracture pattern for ulna? (Tick appropriately)

   - Greenstick
   - Complete
   - Bayonette apposition

8. What is the fracture pattern for the radius?

   - Greenstick
   - Complete
   - Bayonette apposition

9. What is the initial deformity (before casting?)

   - Angulation in coronal plane for radius (degrees)………..
   - Angulation in coronal plane for ulna (degrees)…………
   - Angulation in sagittal plane for radius (degrees)……….
   - Angulation in saggital plane for ulna (degrees)………
   - Cortical translation for radius ………. %
   - Cortical translation for ulna …………%
   - Overlap for radius ……………………mm
   - Overlap for ulna ……………………mm

10. What is the deformity immediately post cast application? (Measurement from the check X-ray)

- Angulation in coronal plane for ulna (degrees)…………
- Angulation in coronal plane for radius (degrees)……….
- Angulation in sagittal plane for ulna (degrees)…………
- Angulation in saggital plane for radius (degrees)……….
- Cortical translation for ulna (%)…………………………%
- Cortical translation for radius (%)………………………%
- Overlap for the radius ……………………………….mm
- Overlap for the ulna ………………………………..mm

11. What is the displacement two weeks after cast application? (Measurement from check X-ray done two weeks post casting)

- Angulation in coronal plane for ulna (degrees)…………….
- Angulation in coronal plane for radius (degrees)…………
- Angulation in saggital plane for ulna (degrees)…………
- Angulation in sagittal plane for radius (degrees)…………….
- Cortical contact for ulna (%)………………………………%
- Cortical contact for radius (%)……………………………. %
- Overlap for the radius ………………………………..mm
- Overlap for the ulna …………………………………..mm

12. cast index measurement

- Diameter of cast in saggital plane……………………..cm
- Diameter of cast in coronal plane…………………….cm
- Cast index ratio …………………..

THE END

APPENDIX 10: ORODHA YA MASWALI YA UTAFITI

Tafadhali weka alama ya 'X' kwenye kijisanduku kilicho karibu na jibu ulilochagua.

Picha za X-ray zitahitajika kwa maswali 3 hadi 12 na pia Mtafiti atakusaidia.

Jina lako kwa ufupi(OP/IP no.)…………….Umri (miaka)………… Tarehe…………..

Jinsia (Mvulana/Msichana) ……….........   Mkono wa kutumika zaidi……………

Uzito (kg)……………..   Urefu (metres)……………………..

1. Je,uliumia lini? (idadi ya siku kufikia leo)…………………………..

2. Je,uliumia vipi?(chagua)

- Kuanguka nikicheza
- Ajali ya barabara
- Kuanguka kutoka juu ya mti au nyumba
- Kupigwa
- Njia zinginezo

KUJIBIWA NA MTAFITI (3 – 12)

3. mvunjiko wa mfupa ulikuwa katika mifupa yote mawili?

- Ndio
- Laa

4.mifupa yote mbili zilivunjika kwa kiwango moja?

- Ndio
- Laa

5.Mfupa ya ulna ulivunjikia wapi?

- Thuluthi ya juu
- Thuluthi ya kati kati
- Thuluthi ya mwisho

6.mfupa ya radius ulivunjikia wapi?

- Thuluthi ya juu
- Thuluthi ya kati kati

- Thuluthi ya mwisho

7. aina ya mvunjiko ya ulna

- Greenstick
- Complete
- Bayonette apposition

8. aina ya mvunjiko ya radius

- Greenstick
- Complete
- Bayonette apposition

9. kiwango ya mifupa kuwachana kabla ya kufungwa plaster

- Angulation in coronal plane for radius (degrees)………..
- Angulation in coronal plane for ulna (degrees)…………
- Angulation in sagittal plane for radius (degrees)……….
- Angulation in saggital plane for ulna (degrees)………
- Cortical translation for radius ………. %
- Cortical translation for ulna …………%
- Overlap for the radius …………………….mm
- Overlap for the ulna ………………………mm

10. kiwango ya mifupa kuwachana baada ya kufungwa plaster, siku ya huduma.

- Angulation in coronal plane for radius (degrees)………..
- Angulation in coronal plane for ulna (degrees)…………
- Angulation in sagittal plane for radius (degrees)……….
- Angulation in saggital plane for ulna (degrees)………
- Cortical translation for radius ………. %
- Cortical translation for ulna …………%
- Overlap for the radius ……………………mm
- Overlap for the ulna ………………………mm

11. kiwango ya mifupa kuwachaana baada ya weeki mbili ya kufungwa plasta

- Angulation in coronal plane for radius (degrees)………..
- Angulation in coronal plane for ulna (degrees)…………
- Angulation in sagittal plane for radius (degrees)……….
- Angulation in saggital plane for ulna (degrees)………
- Cortical translation for radius ………. %
- Cortical translation for ulna …………%
- Overlap for the radius …………………….mm
- Overlap for the ulna ……………………….mm

12. kipimo ya cast index

- Upana kwa sagittal plane …………………cm
- Upana kwa coronal plane ………………...cm
- Cast index ratio…………………

MWISHO

Budget and time planning

Implementation time table

Proposal writing	November 2017 – January 2018
Presenting proposal	May 2018
Submission for ethical approval	May 2018
Data collection and Analysis	June 2018 – July 2018
Dissertation writing	August 2018

Budgetary Costs

Items	**Costs (ksh)**
Research fee (KNH/ERC)	3000
Stationery costs (printing, binding, results, dissertation)	20,000
Statistician and research assistant	45,000
Communication	7,000
Contingencies and Dissemination costs	25,000
Total	**100,000**