REDISPLACEMENT RISK FACTORS FOR SKELETALLY IMMATURE DISTAL RADIUS METAPHYSEAL FRACTURES TREATED BYCAST IMMOBILIZATION IN KENYATTA NATIONAL HOSPITAL

A DISSERTATION SUBMITTED IN PART FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF MASTER OF MEDICINE (M.MED) IN ORTHOPAEDIC SURGERY OF THE UNIVERSITY OF NAIROBI

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H58/82350/2012

DECLARATION

This dissertation has been prepared as part fulfillment of the requirements for the degree of Masters of Medicine in Orthopedic Surgery by the University of Nairobi, School of Medicine. I hereby declare that this study is my original work and has not been presented for a degree course at any other university

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Sign………………………………..

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SUPERVISORS' DECLARATION

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

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CHAIRMAN
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DEDICATION

I dedicate this dissertation to my wife Ms. Cecilia Muoki and to my son Jacen Baraka for their continued encouragement. It would have been difficult to complete this work without their support.

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I thank the Almighty God for giving me the strength and courage to go through this degree programme and to carry out this study.

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LIST OF ABBREVIATIONS

KNH…………………Kenyatta National Hospital

LAR………………….Legally Acceptable Representative

AP……………………Anteroposterior

LAT…………………..Lateral

CT ……………………Computerized Tomogram

K-wire………………..Kirshner wire

CRF………………….Case report form

UoN………………….University of Nairobi

DRUJ………………..Distal radioulnar joint

GA……………………General Anaesthesia

AJOL…………………African journal online

A&E………………….Accident and Emergency

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

Redisplacement:Loss of reduction 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.

ABSTRACT

Background

Distal radius is the commonest site for paediatric forearm fractures. The majority of these fractures are managed by closed reduction and cast immobilization.Maintaining acceptable reduction is not always possible and redisplacement is the most commonly reported complication. The causes of redisplacement are still controversial. Various factors have been studied previously, but there is paucity of data in Kenyatta National Hospital(KNH). Knowledge of significant risk factors will enable early identification of high risk patients and early initiation of alternative management options.

Objective

To determine the risk factors for redisplacement of skeletally immature distal radius metaphyseal fractures managed by closed reduction and cast immobilization in KNH.

Design

Prospective observational study

Setting: KNH Accident and Emergency(A&E), orthopaedic clinic and orthopaedic wards

Patient and methods

58 children aged between 2 and 16 years with consenting legally acceptable representative(LAR) presenting in KNH with displaced distal radius metaphysael fractures were recruited for the study between December 2016 and March 2017. Information was obtained from interviews with the children and their LAR, patients' files and patients' x-rays. Radiographic information was obtained on pre-reduction, immediate post reduction and two weeks post reduction.Analysis was performed using SPSS version 22.

Results

16 out of 58 children had fracture redisplacement at the second week of follow up translating to a redisplacement rate of 27.8%. Most redisplacements occurred in 9-13 year olds. The Male to

Female ratio was 2.2:1.Majority of the children were injured while playing, but the children injured through road traffic accidents had the highest rate of fracture redisplacement at 40%.The commonest fracture type observed was complete displaced fractures.Bayonette apposition fractures had the highest redisplacement rate of 80%, while greenstick fractures had the lowest redisplacement rate of 14.8%.The redisplaced fractures had worse magnitudes of initial displacements with mean displacement measurements of angulations in sagittal plane, coronal plane and percentage cortical translation of 29.8^0,21.6^0,80.5% respectively compared to 20.8^0,$15.5^0$and 69.5%of similar measurements done for the group that did not redisplace.

Fifteen out of 58 children(25.9%) had associated ulna fractures out of which 53.3% of them redisplaced.The fractures were reduced under light sedation or no anaesthesia and both groups had redisplacement rates of 27.8% and 27.3% respectively.Fractures immobilized by a long arm cast had a redisplacement rate of 16.6% while fractures immobilized by a short arm cast had a rate of 30.4%.The redisplaced fractures had a less accurate reduction of 11.1^0,7.9^0 and 29% being angulation in sagittal and coronal plane and percentage of cortical translation respectively compared to undisplaced group's more accurate reduction of 7.2^0,5.0^0 and 15.9% of similar parameters.

Conclusion

The rate of redisplacement of displaced distal radius metaphyseal fractures in skeletally immature patients is 27.8%.

The significant factors for predicting the likelihood of redisplacement of distal radius fractures in children are the duration of time from injury to treatment, the mechanism of injury, the fracture pattern, the initial displacement, presence of an ulna fracture and the accuracy of reduction.

1.0 INTRODUCTION

Fractures of the distal radius are among the commonest childhood injuries[1].They account for most long bone fractures in children, comprising about 40% of all childhood fractures[2,3].The distal radius is the most common site of fracture in the forearm. Blount et al noted that approximately 75% of fractures of the forearm are in the distal third, and that these rarely require open reduction and internal fixation[4]. These fractures occur three times more in boys than girls; however, this ratio may soon change as more girls are participating in sports activities from an early age[5].These fractures occur at any age but they have a peak incidence during the adolescent growth spurt, which in girls is age 11 to 12 years and in boys is 12 to 13 years[5,6]. During this time, there is increased bone remodeling that causes relative osteoporosis of the distal radial metaphysis (where most growth takes place).This makes this area more susceptible to fracture with minimal trauma[5,6].

Displaced fractures of the distal radius in children have a great potential for remodeling unlike adult fractures[7].Consequently they infrequently cause functional impairment. Therefore, non-operative management results in acceptable union and return to pre-injury function. However, redisplacement after the initial fracture reduction and cast immobilization has been reported.[8, 9, 10, and 11]

The success of manipulative reduction depends on maintaining the corrected position in a plaster cast[11].Ojuka, Voto et al noted that there exists a paucity of literature on reasons which are likely to contribute to reangulation or redisplacement of paediatric forearm fractures[10,11]. There are many studies that indicate an incidence of loss of reduction in the 10% to 30% range[8, 11, 12, and 13.]

The factors that contribute to the risk of redisplacement have not been studied conclusively and remain a matter of debate. The age and sex of the patient, the accuracy of the initial reduction, initial degree of displacement of the radius, distance of the fracture from the distal radius physis, association with an ulnar fracture, type of cast used , the experience of the surgeon and the type of anesthesia have all been suggested as risk factors in various studies[8,10,13,14]. Mani et al concluded that initial displacement of the radial shaft of over 50% was the single most reliable predictor of failure of reduction[13]. Proctor et al. found that complete initial displacement resulted in a 52% incidence of redisplacement of distal radial fractures in children[8].

Measurements to assess the accuracy of casting such as the cast index, the Canterbury index , the gap index and the padding index can be used as measures with which to predict the loss of correction of distal metaphyseal radial fractures. However, the accuracy of these indices is questionable, and their value in orthopaedic practice is unclear[15,16].

Below is a table showing a summary of the suggested risk factors for distal radius fracture redisplacement according to Mazzini et al[74]

Table 1: Summary of redisplacement risk factors

Patient related factors	• Patients age • Patients sex
Fracture related factors	• Degree of initial displacement(sagittal and frontal plan angulation, fragment contact) • Fracture pattern (simple, torus, greenstick, complete, displaced , comminuted) • Presence of ulna fracture • Distance from the physis
Treatment related factors	• Accuracy of reduction • Type of cast(long vs. short arm cast) • Type of anaesthesia (GA, conscious sedation, regional block, verbocaine)

In this study, the patients age, gender,time duration between injury and treatment ,the fracture pattern,the amount of initial displacement, presence of an associated ulna fracture, the accuracy of reduction,the type of anaesthesia and the type of cast applied were considered.

2.0 LITERATURE REVIEW

2.1 Anatomy of Distal Radius

The appearance of the distal radius epiphysis is usually about ½ to 2 ½ and ½ to 2 years in boys and girls respectively[17]. The distal radial physeal closure occurs on average at about 16 ½ years of age while the distal ulnar physeal closure occurs about 6 months earlier[18].Both forearm bones articulate distally at the distal radioulnar joint (DRUJ)[19].The radius and ulna have concave distal articular surfaces that articulate with the convex carpus (scaphoid and lunate) to form the wrist joint. These articulations are stabilized by a group of dorsal and volar ligaments so as to allow 120^0 of flexion and extension,50^0 of radial and ulnar deviation and 150^0 of forearm rotation[19].The triangular fibrocartilage compex (TFCC) is the main stabilizer of the ulna-carpal articulation[19,22]. Normally there is negative ulna variance (measured from distal ulna and distal radius metaphysis).Therefore, the distal radiocarpal articulation transmits most of the force (about 80%) explaining the higher rate of distal radius fractures.[20,21]

About 80% of the growth of the forearm is contributed by the distal radius. During the pre-adolescent growth spurt, there is relative osteoporosis in the distal radial metaphysis due to growth outdoing mineral accrual. This reduces the load-strength ratio making the distal radius susceptible to fractures at this age[6, 23, 24, and 25].

2.2 Mechanism of injury

The commonest injury mechanism is a fall on an outstretched hand. The wrist joint is pushed into extension, forcing the distal fragment posteriorly .This kind of injury commonly occurs following a sporting event e.g. soccer goalkeepers, gymnasts [26,27].Distal radius fractures may occasionally be caused by direct trauma to the wrist or the patient falls onto a flexed hand. This usually causes volar displacement or apex posterior angulation. A rotational displacement may be present in any of the injury mechanisms[29]. The extent of displacement is dependent on the amount of energy involved(the falling height and velocity) .Overweight children are at increased risk for distal radius fractures because of their less bone mineralization, ligamentous laxity and poor postural balance[28].The commonest site of cortical failure is the metaphyseal-diaphyseal transition[33].

Distal radius metaphyseal fractures rarely extend into the growth plate to cause growth disturbance[34].

The injured child often presents with history of a fall, wrist pain, marked swelling, restriction of motion and 'diner-fork deformity'. Clinical examination should be aimed at excluding other associated injuries including median and ulnar nerve[32] , compartment syndrome, ipsilateral proximal fractures[31] and fractures of the carpal bones[30].

Anteroposterior and lateral radiographs of the distal radius are usually sufficient to describe the fracture pattern and the degree of displacement. However, the radiographs should include the ipsilateral elbow, forearm, wrist and carpus to rule out other associated injuries[30,31].

Metaphyseal fractures on the radiographs usually appear as cortical buckling, greenstick fractures or complete fractures occurring with or without displacement and loss of radial length. These fractures may occur with an ulnar fracture which occurs at the metaphysis, physis or at the ulnar styloid process[35].

2.3 Classification

Classification of these fractures is based on the pattern of the fracture, the type of displacement and the pattern of associated ulna fracture. The commonest type of fracture displacement is dorsal with an anterior apex angulation[36].The table below summarizes the classification of distal radius fractures[44].

Table 2; Classification of Distal Radius Fractures (Wilkin KE) [44]

Direction of displacement	1.volar 2.dorsal 3.bayonette apposition
Fracture pattern	1.torus 2.greenstick 3.complete
Pattern of associated ulna fracture	1.isolated radius 2.ulna physeal 3.ulna styloid 4.ulna metaphyseal.

2.4 Management

The choice of management modality is influenced by the patients age, fracture pattern, fracture displacement and associated skeletal and soft tissue injuries.Majority of these fractures are managed by closed reduction and casting.

2.5 Remodeling potential

Fractures of the distal radius in children have a remarkable potential for remodelling[37].A 20^0 posterior angulation of these fractures will remodel completely if there are at least two years of growth remaining[38,39,40].According to Friberg, 50% of this remodeling occurs in the first 6 months after the injury while in the next 18months the remaining 50% remodels[40]. However, the physis has to be open for this to occur.[40]

Friberg further observed that remodeling may still occur in angulations of more than 20^0 but the results are unpredictable[39,40].Angular displacement in the coronal plane too has the capacity to remodel but less efficient than sagittal plane[41].Acceptable reduction in the coronal plane is limited due to compromised pronation/supination associated with tilting of more than 10^0.

Due to this great potential for remodeling distal radius fracture have a wide margin of acceptable reduction(table 3) .This makes closed reduction and immobilization a suitable treatment option[43].

2.6 Fracture Reduction Technique

Rang and Fernandez described sequential reduction maneuvers for distal radius metaphyseal fractures; both volar and dorsally displaced fractures. First, initial manipulation is done to accentuate the fracture deformity. It is followed by application of thumb pressure on the dorsal side for apex posterior fractures and volar side for apex anterior fractures, correcting the overriding. This is combined with application of a distal volar pressure together with traction (and counter traction) along the longitudinal plane of radius and ulnar. The accuracy of correction is confirmed on Xray[45,46].

Another technique described involves traction on finger traps[47,48]. However its success was questioned as the periosteum will not readily stretch to allow the reduction[45,46].

2.7 Acceptable Reduction

There are many publications about what margins define an acceptable reduction[38,49,50,51]. Bae et al defined acceptable reduction as 30^0 of sagittal plane angulation if more than five years of growth remain and 5^0 less for each year there after[69].He further defined angulation in frontal plane as 10^0-15^0 if more than 5 years of growth remain[69].Flynn et al accepted angulation of 10^0-20^0 in children aged below 10 years and 10^0 in children aged more than 10 years. He accepted 30^0 of malrotation[70].From these publications, acceptable reduction is clearly dependent on age. This is because remodeling potential is greater in the younger patient[38,49]. The table below summarizes the average guidelines for acceptable reduction.(Lowell and Winters Orthopaedics 7th edition).

Table 3; Acceptable Reduction of Distal Radius Fractures in Children (Lowell and Winters)

Age in years	Sagittal(AP)plane	Coronal(Frontal) plane
4-8	20	15
9-13	15	10
Above 13	10	0

Acceptable fracture contact is 50% or more in all age groups.

After fracture reduction, a cast moulded well over the fracture site and contoured to fit the shape of the forearm is applied using 3 point cast fixation. In dorsally displaced fractures, it means 2 dorsal points proximal and distal to the fracture and one volar point on the fracture site[44].The cast should be applied in slight palmar flexion and ulnar deviation. There are controversies on whether to apply a short arm or a long arm cast[52,53]. Many authors agree that a short arm cast would suffice except for a toddler who is likely to wiggle out of the cast[54,55]. Swelling should be monitored and the cast split if compartment syndrome is suspected. A follow up radiograph should be done one week later to ensure that reduction is maintained[59,60].

2.8 Displacement after Casting

The main drawback associated with closed reduction and immobilization in a cast is loss of reduction. Several authors have found the rate of loss of reduction in the range of 15 to 30%[8,11,12,14,56].Ojuka et al in his study on redisplacement rates after reduction and cast immobilization of isolated distal radius fractures done in KNH found adisplacement rate of 15.7%[11].Proctor et al and Mani et al in their studies found the redisplacement rate to be 23% and 21% respectively[8,61].McQuinn et al in a retrospective of 155 children with distal radius fractures found redisplacement in 33 of them. This translates to a rate of 21.3%[72]. Table 4 below summarizes the redisplacement rates found in different studies.

Table 4: Rates of redisplacement of distal radius fractures

Author	Redisplacement rate
Proctor et al (1993)[8]	23%
Mani et al (1993)[13]	21%
Zamzam et al(2005)[14]	23%
Alemdaroglu et al(2008)[71]	25.3%
Ojuka et al (2010)[11]	15.7%
McQuinn et al (2012)[72]	21.3%
Colaris et al (2013)	29.6%

Voto,Ojuka et al noted that there exists a paucity of literature on reasons likely to contribute to redisplacement[12].

Factors such as the age and sex of the patient, the amount of initial displacement,degree of the accuracy of the initial reduction, distance of the fracture from the distal radius physis, association with an ulnar fracture, type of cast used, the experience of the surgeon and the type of anesthesia have all been suggested as risk factors in various studies[8,10,13,14]

Mazzini, Rodriguez et al[74] noted that the factors causing redisplacement are multifactorial and each of them should not be treated in isolation. In their study on paediatric forearm fractures, they classified these factors as fracture, surgeon and patient related factors.The table below summarizes their classification.

Table 5: SUMMARY OF REDISPLACEMENT RISK FACTORS (Mazzini et al[74])

Patient related factors	• Patients age • Patients sex • Resolution of initial soft tissue swelling. • Non dominant arm.
Fracture related factors	• Degree of initial displacement(sagittal and frontal plan angulation, fragment contact) • Fracture pattern (simple, torus, greenstick, complete, displaced , comminuted) • Presence of ulna fracture • Distance from the physis • Obliquity of the fracture
Treatment related factors	• Accuracy of reduction • Type of cast(long vs. short arm cast) • Type of anaesthesia (GA, conscious sedation, regional block, verbocaine)

Mani et al found out that initial radius displacement of over 50% was the most reliable indicator of impeding fracture redisplacement[61]. Similarly, Proctor et al concluded that a distal radius fracture with complete initial displacement had a 52% redisplacement rate[8]. Gibbons et al noted that isolated radius fractures with complete initial displacement had a remanipulation rate of 91% after closed reduction and cast immobilization alone in comparison to a 0% rate of remanipulation when similar fractures were managed by closed reduction, K- wire fixation, and casting[63]. McQuinn,Jaar et al concluded that the initial displacement and the accuracy of reduction were the most significant factor for redisplacement[72].They concluded that initial translation of more than 50% of the radial width was associated with higher rates of redisplacement.They further concluded that the it is more difficult to achieve anatomic reduction during remanipulation[72].Alemdaroglu et al[71] noted that fractures with complete initial displacement were 11.7 times more likely to redisplace compared to incompletely displaced fractures.

Distal radius metaphyseal fractures are common from the age of 5 years with peak incidence at 12-14 years in boys and 10-12 years in girls[74].Redisplacement is likely to be common in these age groups.

These fractures occur three times more in boys than girls; however, this ratio may soon change as more girls are participating in sports activities from an early age[5.]

Alemdaroglu et al[71] described a new factor: obliquity of the fracture. He found the fracture obliquity to be as significant as the degree of initial displacement.According to his study findings, 20^0 oblique fractures were 4.9 times more likely to displace while 30^0oblique fractures were 10.9 times more likely to redisplace. These findings were in comparison to 0^0 transverse fractures.

Associated ulna fracture’s influence on redisplacement has been described.However, several authors have had differing conclusions. Zamzam et al[14],Bohm et al[55]identified presence of ulna fracture as a significant factor. Gibbons et al[63] concluded that isolated fractures of the distal radius were more unstable and therefore more likely to reangulate than with a concurrent ulna fracture.Alemdaroglu et al[71] did not find any significant contribution of an ulna fracture to redisplacement.

The proximity of the fracture to the distal radius physis has been described as a risk factor.Mazzini et al[74]noted better prognosis with fractures that are closer to the physis.Alemdaroglu et al[71] concluded that the distance from the physis does not significantly affect the rate of redisplacement.

Most authors concur that the accuracy of reduction significantly influences the rate of redisplacement.The accuracy of reduction is age related.Noonan and Price et al[75] concluded that children less that 9 years of age are likely to heal with complete translation and angulation of less than 15^0.He further found that children older than 9 years with completely translated fractures and more than 10^0 of angulation were likely to result into malunion.Bae et al[69] noted that the closer to anatomical reduction the fracture is, the lesser the likelihood to displace.

There are controversies on whether to apply a short arm or a long arm cast[52,53]. Many authors agree that a short arm cast would suffice except for a toddler who is likely to wiggle out of the cast[54,55].Chess et al found out that short arm casts are highly effective in maintaining reduction of all fracture patterns[52].Bohm et al compared short and long arm cast results and found no significant difference between them[55].The complication rates were similar in both groups.Similarly,Webb et al in his study on comparison of long and short arm casts found no significant difference in demographic, fracturecharacteristics, mechanism of injury and cast index during treatment[54].

These studies advocate for closed manipulation and percutaneous pinning of distal radial fractures that are at risk of redisplacement.

The indications for percutaneous pinning include;

1. Fracture instability and high risk of loss of reduction[8]
2. Excessive local swelling that increases the risk of neurovascular compromise[56]
3. Ipsilateral fractures of the distal radius and elbow region (floating elbow)[57]
4. Likelihood that remanipulation will be required (Widmann et al)[58]
5. Open fractures.

The average time to redisplacement averages 10-14 days from the time of injury[67]. Lefvre et al in his study showed difficulties in closed reduction 10-15 days after injury[67]. Chivers et al recommended follow up radiographs at 2 weeks after the injury[76].

3.0 STUDY QUESTION

What are the risk factors influencing redisplacement of distal metaphyseal radius fractures managed by closed reduction and cast immobilization in skeletally immature patients in Kenyatta National Hospital?

4.0 STUDY JUSTIFICATION

Distal radius metaphyseal fractures are the commonest fracture in children. Most of these fractures are managed by closed reduction and cast immobilization. Redisplacement after cast immobilization is the most common complication of these fractures.Uncorrected redisplacement leads to malunion and compromised forearm function. Several factors responsible for redisplacement have been studied in numerous studies. There is local paucity of data on redisplacement of paediatric distal radius fractures. Only one study has been done in KNH.

Knowledge of these factors will enable early prediction of impeding redisplacement. The surgeon is therefore able to engage preventive measures or institute early alternative management options such as closed reduction and percutaneous pinning. Early identification of fractures that are likely to displace and early initiation of operative management prevents remanipulation, repeated x-rays and reduces outpatient follow up visits.

5.0 STUDY OBJECTIVES

5.1 Main objective

To determine the risk factors for redisplacement of distal radius metaphyseal fractures in skeletally immature patients treated by cast immobilization in Kenyatta National Hospital.

5.2 Specific objectives

i. To determine the rate of redisplacement of distal radius metaphyseal fractures in skeletally immature patients treated by cast immobilization in KNH.

ii. To determine the pattern of displaced distal radius metaphyseal fractures in skeletally immature patients treated by cast immobilization in KNH.

iii. To determine the effect of fracture related factors(initial displacement, accuracy of reduction and ulna fracture) on redisplacement of distal radius metaphyseal fractures treated by cast immobilization in KNH

iv. To determine the effect of treatment and patient related factors(age,gender,time duration from injury to treatment, type of cast, type of anaesthesia,time duration from injury to treatment) on redisplacement of distal radius metaphyseal fractures treated by cast immobilization in KNH.

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6.0 METHODOLOGY

6.1 Study Design

Prospective observational study

6.2 Study Setting

The study was conducted at the Orthopaedic outpatient clinic,KNH A&E,Paediatric Orthopaedic ward of Kenyatta National Hospital (KNH). KNH is the largest Kenyan referral hospital located in the capital city, Nairobi.

6.3 Study Population

All children aged 2 and 16 years with consenting legally acceptable representative presenting in KNH with displaced distal radius metaphyseal fracture were considered in this study.

Distal radius fractures are rare before 2 years of age. Children above 16 years of age may have closure of the growth plate and the management principles follow those of adult distal radius fractures[18].

6.4 Sample Size

Ojuka et al in his study published in 2010 in the Africa Journal online(AJOL) found the rate of redisplacement of paediatric distal radius fractures to be 20.3%.The study used Fisher *et al* (1998) to obtain a sample size. The Fisher *et al* (1998) formula used is illustrated as shown below;

$n=Z^2xp(1-p)/d^2$

Where;

n = Sample size for large population

Z = Normal distribution Z value score, (1.96)

p = Proportion of units in the sample size possessing the variables under study, where for this study it is set at 20.3% (0.203)

d = Precision level desired or the significance level which is 0.1 for the study

The substituted values in determining the sample size for a large population are as follows;

$$n = \frac{(1.96)^2 \ (0.203) \ (0.75)}{(0.1)^2}$$

n = 58

6.5 Inclusion Criteria

1. Skeletally immature Male or female child aged 2 to 16 years.
2. A radiologically confirmed displaced distal radius fracture treated by cast immobilization.
3. Willingness of the child's legally acceptable representative (LAR) to confirm participation by written informed consent.
4. Patients with acceptable reduction.

6.6 Exclusion criteria

1. LAR declining consent.
2. Compound distal radius fracture.
3. Distal radius fracture treated by operative means.
4. fractures with unacceptable reduction.

6.7 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 distal radius fractures and those who fulfill 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, examined them and studied their radiographs before and after cast application. A follow up radiograph was taken two weeks after cast application and studied.

The degree of angulation in the coronal and sagittal planes as well as the percentage translation between the fracture fragments were measured.The angle of angulation was the goniometric measurement of the angle formed by lines drawn in the longitudinal axis of the proximal and distal fragments passing in the middle of the medullary canal. Sagittal angulation was measured in the Lateral radiograph while coronal angulation was measured on the AP radiograph. These measurements are described by JA Roberts on his paper on angulation of distal radius fractures in children[68].

Acceptable reduction was based on the values in table 3(Lowell and Winter's Paediatric Orthopaedics 7th edition).

Data was collected using Case Report Forms (CRF) administered by the researcher and research assistants. The data collected was:

1. Age and sex of the patient
2. Date and time of injury
3. Date and time of reduction
4. Pattern of fracture sustained
5. Pattern of displacement(degree of angulation in sagittal and coronal planes,% loss of cortical contact)
6. Presence of ulna fracture
7. Type of cast (short arm or long arm)
8. Degree of displacement immediately and two weeks after cast application.
9. The type of anaesthesia used(local,regional,iv sedation,general anaesthesia)

6.8 Data management

Data was transferred from CRF to electronic format. Analysis was performed using spss v22. Descriptive analysis was used for demographic characteristics, mechanism of injury and fracture pattern. Means, proportions, percentages, ranges and standard deviations were used to analyze each of the specific objectives.

7.0 ETHICAL CONSIDERATIONS

Written approval of this study was sought from the University of Nairobi department of orthopedic surgeryand Kenyatta National Hospital Ethics Research Committee before conducting any activity related to the study.

All patients were given written informed consent after details of the study have been explained to them (purpose, methods, potential harm or benefits).

All patients received standard care offered at KNH.

Children found to have fractures with unacceptable reduction were referred to the plaster technician, orthopaedic resident or surgeon on duty for intervention.

The doctor/surgeon on duty was notified on those children found to have fracture redisplacement for further intervention.

The investigator ensured that the patient's privacy was maintained.

No confidential information obtained from the patients was disclosed to any other parties without the patient's consent.

No data obtained from this study has been used for any other purpose other than meeting the objectives stated in this dissertation.

All data generated from this study was surrendered to the Department of Orthopaedic Surgery, University of Nairobi and KNH in order to aid in policy change.

8.0 STUDY LIMITATIONS

- Fracture reduction and cast application was done by different residents or plaster technicians. This may present variation.
- Data was collected from a single centre.
- There were patient losses to follow up.
- Difficulty obtaining consent in children brought in by good Samaritans or street children.

9.0 RESULTS

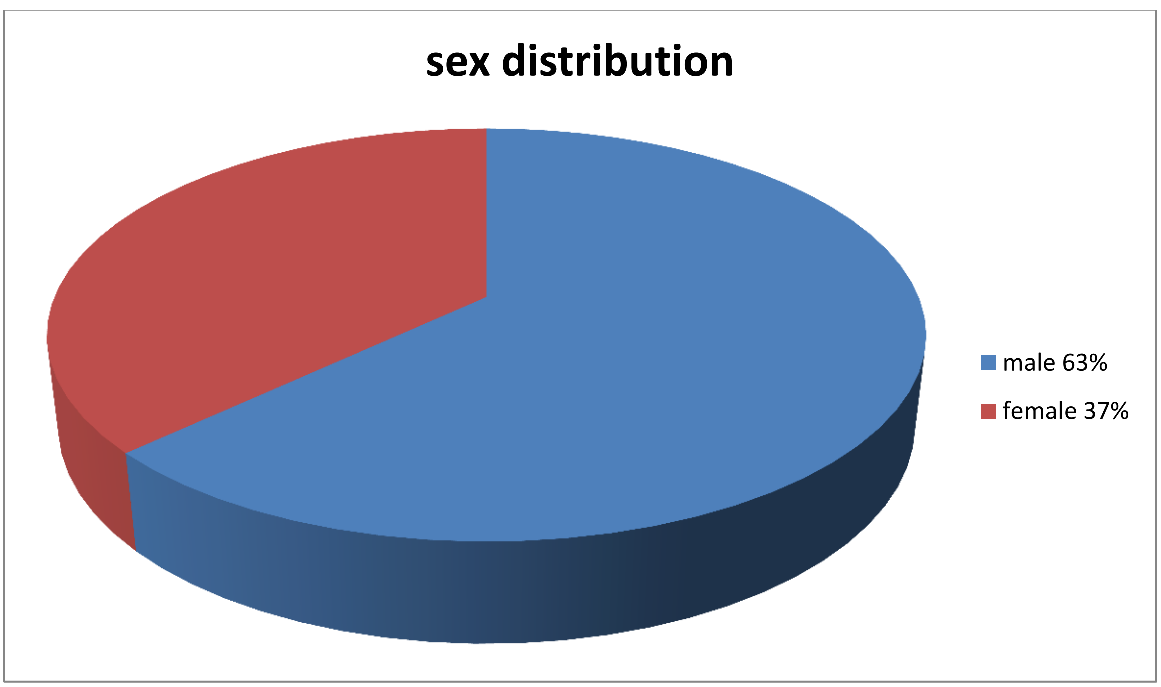
A total of sixty children with displaced distal radius metaphyseal fractures were recruited into the study.Two of them were lost during follow up(they didn't attend the follow up visit two weeks after casting) leaving a total of fifty eight children.

The children were aged between four years and fifteen years.Their ages were grouped into age clusters as shown on table 5.The mean age was ten years.Thirty six of them were boys while twenty two were girls (sixty two percent were boys and thirty eight percent were girls)

Table 6: age distribution

Age cluster	Number	Percentage(%)
4-8 years	24	41%
9-13 years	30	52%
Over 13 years	4	7%

Figure 1:A pie chart showing sex distribution



The duration of time between occurrence of injury and time of casting was determined and grouped in days .Thirty two children presented for treatment within the first 24 hours from the time of injury.Fifteen children presented on the second day, six of them presented on the third day. One child presented on the fourth day while 2 others presented on the fifth day. There was one child each presenting on the seventh and eighth day. This is summarized on table 6.

Table 7: Time duration between injury and treatment

No. of days	No. of children	Percentage
One	32	55.2%
Two	15	25.9%
Three	6	10.3%
Four	1	1.7%
Five	2	3.4%
Seven	1	1.7%
Eight	1	1.7%

The mechanism of injury was determined for all the fifty eight children. Forty of them sustained distal radius fracture while playing. Twelve of them fell from height, mostly from trees, while five sustained fractures as a result of road traffic accidents. One child was assaulted –he was hit by an older child. Table 7summarizes the mechanisms of injuries.

Table 8: Mechanisms of injury

Mechanism of injury	**Number of children**	**Percentage**
Injured while playing	40	69.0%
Fell from height	12	20.7%
Road traffic accident	5	8.6%
Assault	1	1.7%

The fracture patterns were determined from the radiographs taken before fracture reduction. All fractures were displaced to warrant closed manipulation and casting. There were forty displaced complete fractures, fourteen displaced greenstick fractures and four fractures with bayonette apposition. This is summarized on table 8 below.

Table 9: Fracture patterns observed

Fracture pattern	**Number of fractures**	**Percentage**
Complete fractures(displaced)	39	67.2%
Greenstick fractures(displaced)	14	24.1%
Bayonette apposition	5	8.6%

Goniometric measurements of angulations in coronal plane were done on the Anteroposterior film, sagittal plane angulations done on the lateral films and percentage cortical translation done on the lateral film.

The amount of initial displacement was grouped according to age, based on the acceptable displacements for different age groups(table 3).They were also grouped according to the type of displacement, that is, whether sagittal or coronal angulation and the percentage of cortical translation. The mean amount of displacement for all the age groups were calculated and grouped as shown in table 9.

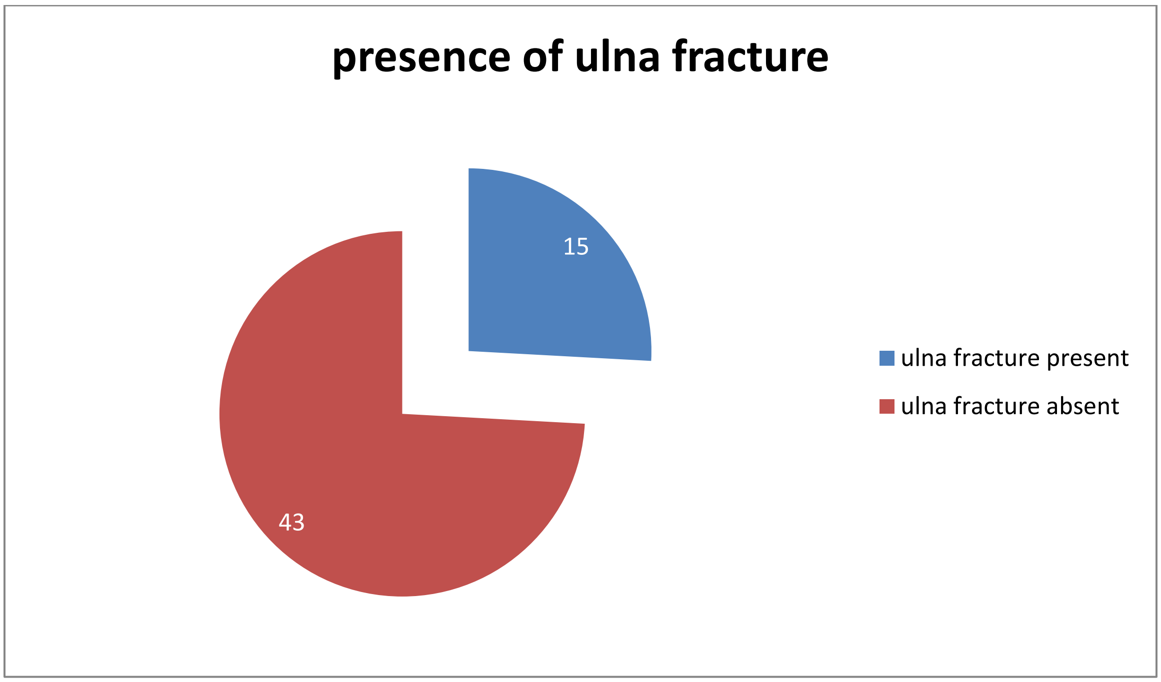
Table 10:Mean initial displacement

Age group (years)	**Mean amount of initial displacement**		
	Sagittal plane(degrees	**Coronal plane(degree**	**Cortical translation(%**
4-8	24.3^0	17.5^0	56.2%
9-13	23.6^0	16.8^0	81.5%
0ver 13	19.5^0	14.4^0	75.1%

The mean displacement for all the age groups for sagittal. Coronal and cortical translations was 22.5^0,16.3^0 and 70.9% respectively.

Fifteen of the fractures had associated ulna fractures(28.5%).fourteen were ulna metaphyseal and two were ulna physeal.

Figure 2:A pie chart showing the presence of ulna fracture



Fracture reduction was done either under conscious/light sedation(parenteral morphine and diazepam) or without any anaesthesia. Thirty six fractures (62%) were reduced without anaesthesia while twenty two fractures (38%) were reduced under light sedation.
Casting was done with Plaster Of Paris for all the fractures. A short arm cast was used in forty six out of fifty eight fractures while a long arm cast was done for twenty two fractures.

Table 11:Type of Anaesthesia used

Type of anesthesia	**Number**	**Percentage**
No anaesthesia	36	62.0%
Light sedation	22	38.0%
GA,regional,local	0	0%

Table 12: type of cast used

Type of cast	**Number**	**Percentage**
Short arm cast	46	79.3%
Long arm cast	12	20.7%

Check radiographs were done immediately after casting.In this study, all the fractures were satisfactorily reduced based on the exclusion criteria. Fractures with unacceptable reduction were not recruited into this study but were referred to the casting room for remanipulation.

To determine the accuracy of reduction, goniometric measurements of the same parameters were done for all fifty eight fractures. Although some of these fractures were still displaced after closed manipulation and casting ,the displacement was within the acceptable reduction for different age groups. Complete remodeling is expected to occur if the reduction is maintained.The mean displacements immediately post cast application were calculated and tabulated on table 12 below according to their age groups.

Table 13;Satisfactorydisplacements immediately after casting

Age group (years)	**Mean amount of acceptable displacement**		
	Sagittal plane(degrees	**Coronal plane(degree**	**Cortical translation(%**
4-8	9.0^0	5.3^0	8.9%
9-13	8.1^0	6.1^0	18.8%
0ver 13	4.5^0	3.6^0	20.0%

The mean acceptable displacement for all age groups for sagittal, coronal and cortical translation was 7.2^0,5.0^0 and 15.9% respectively.

Redisplacement rate

All 58 children were followed up for two weeks. At the end of week two, a check x-ray was done and the radiographic parameters (angular displacements in sagittal and coronal planes and percentage cortical translation) were measured.

Sixteen out of fifty eight children had fractures that redisplaced beyond the acceptable displacement for their age group. This translates to 27.6 % rate of redisplacement. These children were referred to the fracture clinic for remanipulation or operative management and were not followed any further in this study.

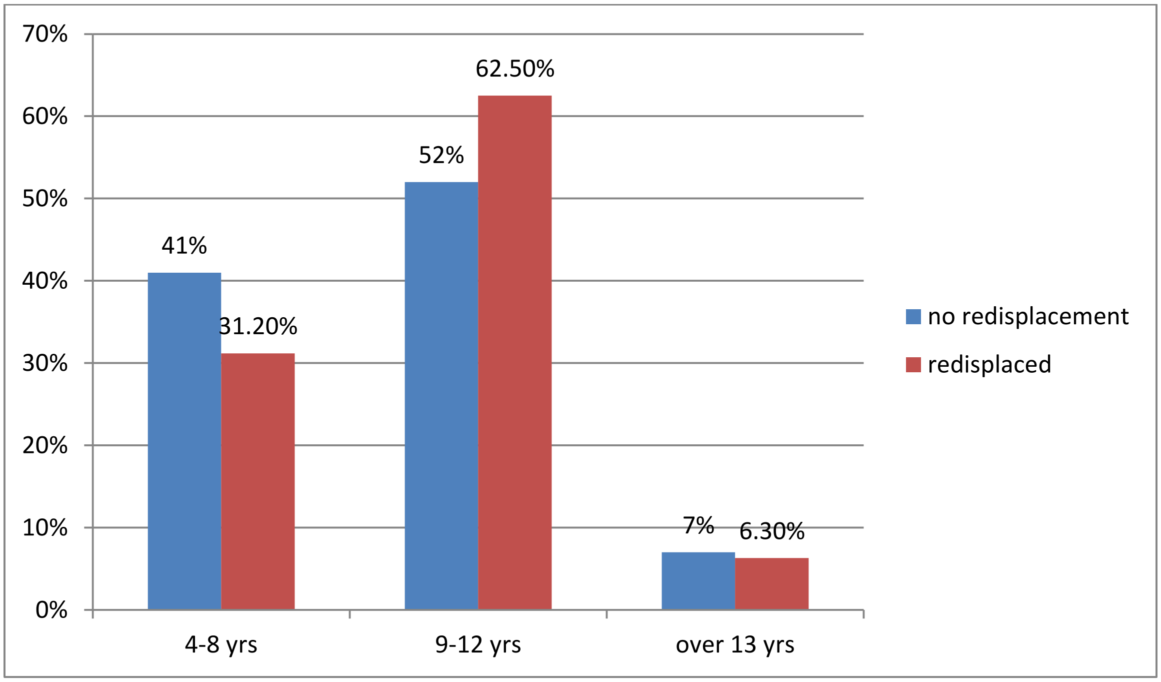
Effect of age on the rate of displacement.

The redisplaced fractures were grouped according to the age groups. The pattern of distribution was similar to the whole group.The mean age for the redisplaced group was ten years. The mean age for the group without displacement was ten years as well. Table 13 below shows age distribution of redisplaced fractures. Comparison between the two groups was made and the findings presented in the graph shown below(figure 3).The pattern of distribution appears similar between the redisplaced and undisplaced groups.

Table 14: age distribution for redisplaced fractures

Age cluster	**Number**	**Percentage (%)**
4-8 years	5	31.3%
9-13 years	10	62.5%
Over 13 years	1	6.3%

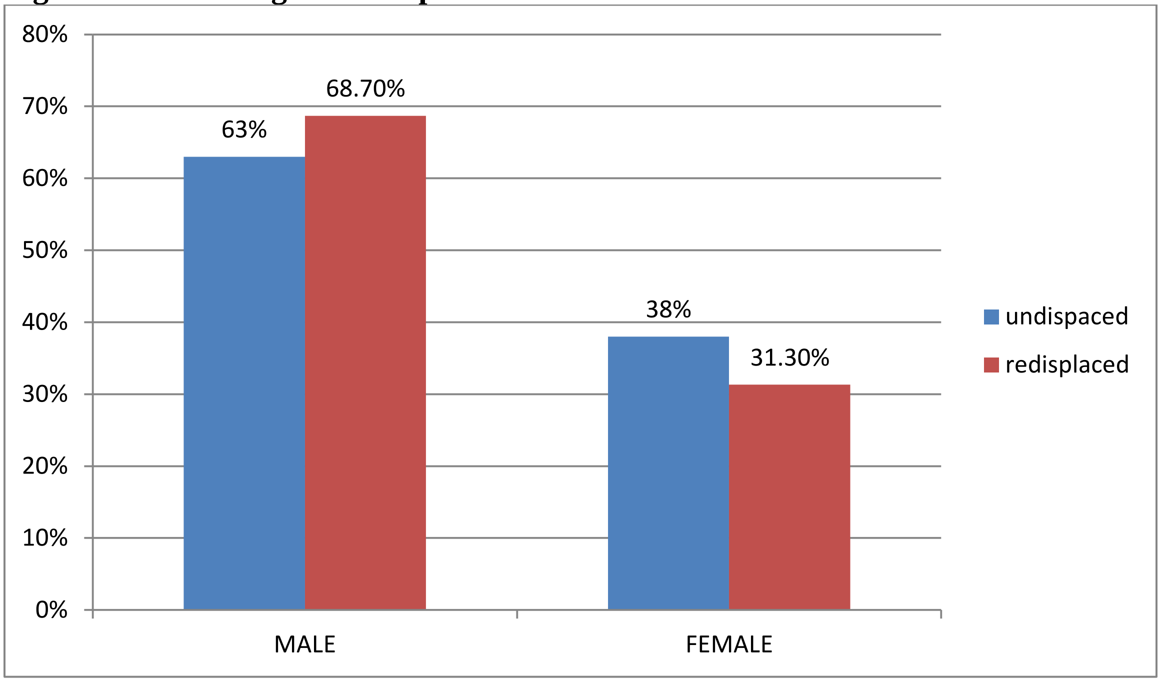
Figure 3:Distribution according to age of redisplaced and undisplaced group.



Effect of gender on redisplacement

Out of the sixteen children with redisplaced fractures, five were female (31.3%) and eleven were male (68.8%).This gives a M:F ratio of 2.2:1.The males and females in the undisplaced group were 68.7 % and 31.3% respectively. The distribution pattern appears similar in both groups. Figure 4 below shows comparisons between the two groups.

Figure 4: effect of age on redisplacement



Effect of time duration between injury and treatment.

Table 15: Effect of Time duration between injury and treatment

No. of days	No. of children(All)	No.of children(redisplaced)
One	32	5
Two	15	4
Three	6	3
Four	1	1
Five	2	1
Seven	1	1
Eight	1	1

The time duration between injury and treatment is as tabulated on table 14 above. Five out of thirty two children who presented on the first day had redisplaced fractures, translating to 15.6 percent. Day 2 had 26.7 %redisplacement rate. Day 3 had 50 %.Each of the children presenting on day four, seven and eight had displaced distal radius fractures. The mean duration between injury and treatment is 1.2 days for the undisplaced group and 2.7 days for the redisplaced group. This shows that the time duration for the redisplaced fractures was more.

Effect of the mechanism of injury on redisplacement

The mechanism of injury in the redisplaced group was compared to the undisplaced group and the results expressed in percentages. Table 15 below shows comparisons of the mechanisms of injury between the two groups.The largest percentage was noted in the group that was injured through road traffic accidents.

Table 16: Redisplacement rates according to mechanisms of injury.

Mechanism of injury	**Total number of children**	**Number of redisplaced fractures**	**Percentage**
Injured while playing	40	10	25.0%
Fell from height	12	4	33.3%
Road traffic accident	5	2	40.0%
Assault	1	0	0.0%

Effect of the fracture pattern on the rate of redisplacement

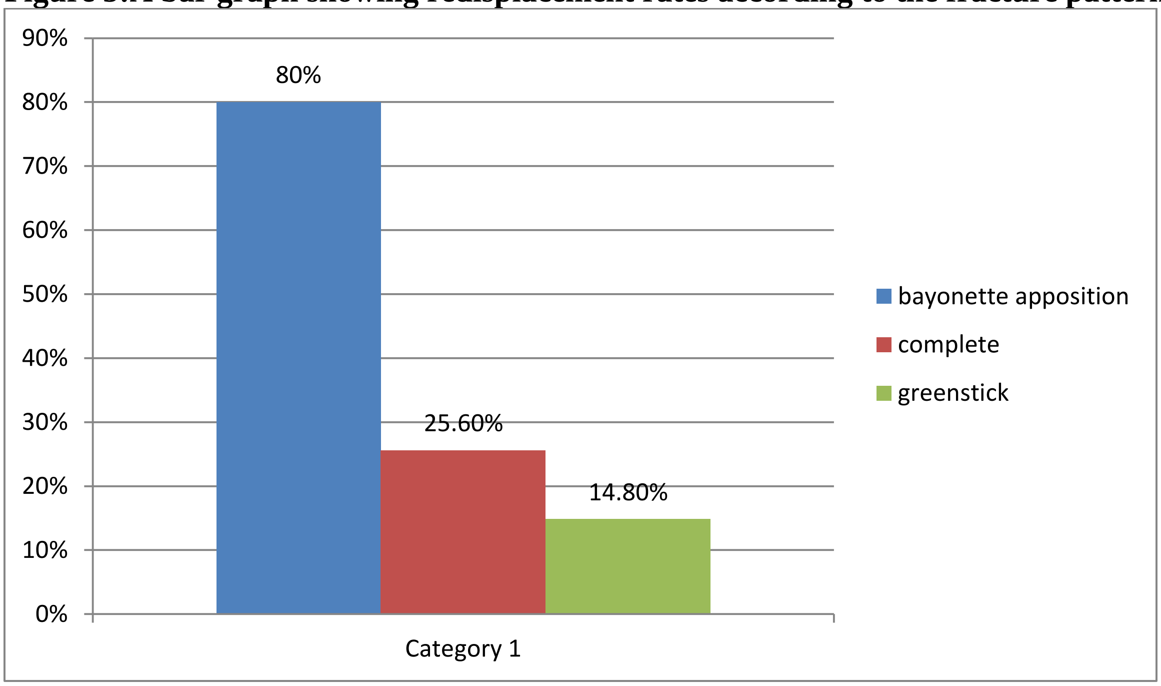
The fracture patterns noted were greenstick,complete and bayonette apposition types(table 9).The redisplaced fracture pattern was noted and compared to the pattern for the whole group. Two greenstick fractures, ten complete fractures and four fractures with bayonette apposition redisplaced. These findings are summarized on table 16 below.

Considering bayonette apposition, complete and greenstick fractures alone, the displacement rate was eighty, twenty five and fourteen percent respectively. Figure 3 is a bar graph comparing the three fracture patterns.

Table 17:Redisplacement rate according to fracture pattern

Fracture pattern	Number of fractures	Redisplaced fractures	Redisplacement rate
Complete fractures(displaced)	39	10	25.6%
Greenstick fractures(displaced)	14	2	14.3%
Bayonette apposition	5	4	80%

Figure 5:A bar graph showing redisplacement rates according to the fracture pattern



Effect of the initial displacement on redisplacement rate

The amount of initial displacement was compared between the redisplaced and satisfactory group. Table 17 below summarizes the mean displacement in the sagittal plane, coronal plane and cortical translation according to age groups.

Table 18: Mean initial displacement in redisplaced and satisfactory group

Age group (years)	**Mean amount of initial displacement**					
	Sagittal plane(degrees)		**Coronal plane(degrees)**		**Cortical translation (%)**	
	S	**R**	**S**	**R**	**S**	**R**
4-8	22.2^0	29.8^0	16.4^0	22.4^0	54.3%	68.6%
9-13	21.8^0	28.6^0	15.8^0	20.8^0	79.4%	92.3%
0ver 13	18.4^0	26.4	14.2^0	21.1^0	74.1%	80.4%
All ages	$\mathbf{20.8^0}$	$\mathbf{29.1^0}$	$\mathbf{15.5^0}$	$\mathbf{21.6^0}$	**69.3%**	**80.5%**

S…. satisfactory group

R…..redisplaced group

The mean displacement in the sagittal plane for the satisfactory group was 20.8^0 while the undisplaced group had 29.1^0.Similarly the mean displacement in the coronal plane and the cortical translation was 15.5^0 and 69.3% respectively compared to 21.6^0 and 80.5% for the redisplaced groups. The redisplaced fractures had more displacements than those fractures that did not redisplace.

Effect of the presence of ulna fracture on the redisplacement rate

Fifteen out the total fifty eight children had associated ulna fractures. Out of the fifteen children with associated ulna fractures, eight of them had a redisplaced distal radius fracture at two weeks. When expressed in percentages,25.8% of the total sample under study had associated ulna fractures while 53.3% of those with associated fractures had redisplaced distal radius fractures.This means that the rate of redisplacement among distal radius and ulna fractures is 53.3%.

Effect of the type of anaesthesia on the redisplacement rate

In this study the type on anaesthesia used was either light sedation or no anaesthesia .The type of anaesthesia used for the redisplaced group was compared to the whole group .This is summarized below on table 18.

Table 19:redisplacement vs.type of anaesthesia used.

Type of anesthesia	**Total number**	**Redisplaced**	**% redisplacement**
No anaesthesia	36	10	27.8%
Light sedation	22	6	27.3%

The redisplacement rate in the light sedation group was 27.3% while redisplacement rate in the No anaesthesia group was 27.8%.The redisplacement rate is similar between the light sedation and no anaesthesia groups.

Effect of the type of cast on the redisplacement rate.

Most of the redisplaced fractures were immobilized with a short arm cast (fourteen) and only two were immobilized with a long arm cast.30.4% of the short arm cast group redisplaced while 16.6% of the long arm cast group redisplaced. However, the children whose fractures were immobilized by a long arm cast were between four and six years. The majority of children with redisplaced fractures were between eight and thirteen years(table 13).Table 19 summarizes the effect of cast type on the redisplacement rate.

Table 20: type of cast used and the redisplacement rate

Type of cast	Number	Redisplaced	% redisplacement
Short arm cast	46	14	30.4%
Long arm cast	12	2	16.7%

Effect of the accuracy of reduction on the rate of redisplacement

The accuracy of reduction, determined on the immediate post casting radiographs, is as shown on table 13.The accuracy of reduction for the redisplaced group was compared to that of the satisfactory group. The mean amount of acceptable reduction in sagittal plane,coronal plane and cortical translation for the redisplaced group was 11.1^0,7.9^0 and 29% respectively. The satisfactory group had a more accurate mean reduction at 7.2^0,5.0^0 and 15.9% displacements in the sagittal plane, coronal plane and cortical translation respectively. These findings are summarized on table 21.

Table 21: Accuracy of reduction

Age group (years)	**Mean amount of acceptable displacement**					
	Sagittal plane(degrees		**Coronal plane(degree**		**Cortical translation(%**	
	Satisfactory	Redisplaced	satisfactory	Redisplaced	Satisfactory	Redisplaced
4-8	9.0^0	16^0	5.3^0	10.0^0	8.9%	26.7%
9-13	8.1^0	11.2^0	6.1^0	8.7^0	18.8%	35.2%
0ver 13	4.5^0	6.0^0	3.6^0	5.0^0	20.0%	25.0%
All	$\mathbf{7.2^0}$	$\mathbf{11.1^0}$	$\mathbf{5.0^0}$	$\mathbf{7.9^0}$	**15.9%**	**29.0%**

10.0 DISCUSSION

Redisplacement rate.

The main treatment modality for closed distal radius metaphyseal fractures in children has been closed manipulation and immobilization in a cast. The main drawback associated with closed reduction and immobilization in a cast is loss of reduction(redisplacement). This leads to malunion, reduced function and unacceptable cosmetic results.

This study found a total redisplacement rate of 27.6% .This is comparable to redisplacement rates found in several other studies.

Several authors have found the rate of loss of reduction in the range of 15 to 30%[8,11,12,14,56].Ojuka et al in his study on redisplacement rates after reduction and cast immobilization of isolated distal radius fractures done in KNH found a redisplacement rate of 15.7%[11]considering both displaced and undisplaced fractures. Proctor et al and Mani et al in their studies found the redisplacement rate to be 23% and 21% respectively[8,61].McQuinn et al in a retrospective of 155 children with distal radius fractures found redisplacement in 33 of them.This translates to a rate of 21.3%[72].

This study considered redisplacement in fractures that were initially displaced. Most of the studies done considered loss of reduction irrespective of the initial magnitude of displacement. However, considering initially displaced fractures alone the redisplacement rates are much higher.Ojuka et al found a redisplacement rate of 0.3% at week two and 21.9% at week two considering greenstick and completely displaced fractures seperately[11]. The overall rate of redisplacement was 15.7% for all distal radius fractures with or without initial displacement[11].Colaris et al found a redisplacement rate of 29.6% in their study on displaced paediatric distal radius fractures[71].Asdollahi et al found redisplacement in 39 out of 135 children with a redisplacement rate of 28.8%[75].

Risk factors for redisplacement

Voto,Ojuka et al noted that there exists a paucity of literature on reasons likely to contribute to redisplacement[12].

Factors such as the age and sex of the patient, the amount of initial displacement, degree of the accuracy of the initial reduction, distance of the fracture from the distal radius physis, association with an ulnar fracture, type of cast used, the experience of the surgeon and the type of anesthesia have all been suggested as risk factors in various studies[8,10,13,14]

Mazzini,Rodriguez et al[74] noted that the factors causing redisplacement are multifactorial and each of them should not be treated in isolation. They further classified these factors as patient related, fracture related and treatment related factors.

In this study, we considered the following factors likely to contribute to redisplacement;

1. Age of the patient
2. Sex of the patient
3. Time duration between injury and treatment
4. Mechanism of injury
5. Fracture pattern
6. Amount of initial displacement
7. Presence of associated ulna fracture
8. Type of anaesthesia used
9. Type of casting used
10. Accuracy of reduction

Age of the patient.

The majority of the children seen in this study were aged between nine and thirteen years of age,accounting for 59% of the total study population. The mean age for all children in this study was ten years.

Most of the redisplaced fractures were also observed in the same age group that is nine to thirteen years of age,accounting for 62.5% of all the redisplaced fractures. Similarly, the mean age in the redisplaced group was ten years.

The higher rate of redisplacement observed in this age group could be attributed to the fact that most of the distal radius metaphyseal fractures peak during this age group. According to Chivers et al,distal radius metaphyseal fractures are common from the age of 5 years with peak incidence at 12-14 years in boys and 10-12 years in girls[74].Redisplacement is likely to be common in these age groups. Asdollahi et al in their study on redisplaced distal radius fractures had a mean age of 9.9 years with most redisplacements occurring around this age[75].

Bailey and Boyd et al noted that during the pre-adolescent growth spurt, there is relative osteoporosis in the distal radial metaphysis due to growth outdoing mineral accrual. This reduces the load-strength ratio making the distal radius susceptible to fractures at this age[6, 23, 24, and 25].

Therefore age does not impact on redisplacement but rather a factor for predicting remodeling potential.

Effect of sex on redisplacement

The study population had 36 boys and 22 girls, making a male to female ratio of 1.6:1.out of this, eleven boys and five girls redisplaced,making a male to female ratio of 2.2:1.There is no significant difference between the male to female ratios in the whole study population and the redisplayed group. This compares to the ratio of between 1.8:1 and 3:1 found in other literature[5,11]

The higher incidence of distal radius fracture in boys than girls is attributed to the fact that boys are more outgoing and more active than girls.

Nishiyama et al noted that these fractures occur three times more in boys than girls; however, this ratio may soon change as more girls are participating in sports activities from an early age[5].In their comparison of distal radius between boys and girls, they concluded that the male distal radius was more porous than the female one during the pubertal growth spurt[5].

Time duration between injury and treatment

The mean time duration between injury and treatment for the group without redisplacement was 1.2 days while it was 2.3 days for the redisplaced group. Most of the children presenting on the 4th and 5th days eventually had redisplaced fractures. This may be attributed to the possibility that most of the children presenting after the first day may have had unsuccessful reduction attempts in other facilities, but finally being referred to KNH.

There is scarcity of data on delayed distal radius fracture presentation. Most articles available describe management of malunited fractures. Bibiana et al recommended surgical intervention for displaced fractures presenting more than five days[77].

The mechanism of injury in relation to redisplacement

Most of the children in this study (68.9%) were injured while playing mostly football. Twenty point seven percent fell from a height, majority of them having fallen from fruit trees and 8.6% were involved in road traffic accidents.The highest redisplacement rate was noted in the road traffic accident group (40%), followed by the group that fell from a height (33.3%).

This could be due to the higher magnitude of displacement seen in the groups which points to a greater energy involved in these injury mechanisms.

These findings are comparable to what authors have found in other literature.

According to Kocher and Waters et al distal radius fractures commonly occurs following a sporting event e.g. soccer, goalkeepers, gymnasts [26,27]. Tarr et al concluded that the extent of displacement is dependent on the amount of energy involved(the falling height and velocity)[28].

The fracture pattern

This study considered displaced fractures only.Among the displaced fractures, the most common fracture pattern observed was complete displaced fractures forming about 68.9 % of the study population. Greenstick fractures and bayonette apposition fractures were 24.1 % and 7% respectively.

When each fracture pattern was considered separately in terms of redisplacement, bayonette apposition fractures had a redisplacement rate of 80% while complete displaced fractures and greenstick fractures had a redisplacement rate of 25.6% and 14.8% respectively.

This study therefore found out that distal radius metaphyseal fractures with an overriding displacement had the highest rate of fracture redisplacement.

Other studies have found a redisplacement rate of greenstick fractures of between 10% and 16%[67]. Proctor et al found a redisplacement rate of 73% if completely displaced fractures were considered alone.

According to Waters PM et al, an overriding displacement of a distal radius metaphyseal fracture in children was a significant risk factor for redisplacement[55].Gibbons et al found a redisplacement rate of 91% in bayonete apposition distal radius fractures.

Initial displacement as a redisplacement factor

Angulation in coronal and sagittal plane together with the amount of cortical translation in this study was a significant factor in predicting redisplacement. The redisplaced fractures were more angulated with more degrees of cortical translation than those that did not redisplace. Several other studies done had similar findings.

Mani et al found out that initial radius displacement of over 50% was the most reliable indicator of impeding fracture redisplacement[61]. Similarly, Proctor et al concluded that a distal radius fracture with complete initial displacement had a 52% redisplacement rate[8]. Gibbons et al noted that isolated radius fractures with complete initial displacement had a remanipulation rate of 91% after closed reduction and cast immobilization alone in comparison to a 0% rate of remanipulation when similar fractures were managed by closed reduction, K- wire fixation, and casting[63].

Alemdaroglu et al[71]in his study on redisplacement of distal radial fractures in children, noted that fractures with complete initial displacement were more likely to redisplace compared to incompletely displaced fractures.They concluded that initial complete displacement was the dominant factor influencing fracture redisplacement.

Asadollahi et al found out that completely displaced distal radius fractures were seven times more likely to redisplace that fracture with cortical contact.[75]

McQuinn,Jaar et al concluded that the initial displacement and the accuracy of reduction were the most significant factor for redisplacement[72].They concluded that initial translation of more than 50% of the radial width was associated with higher rates of redisplacement. They further concluded that the it is more difficult to achieve anatomic reduction during remanipulation.[72]

Hang JR et al in their retrospective study on risk factors associated with loss of fracture position, identified initial radial fracture displacement as a significant independent clinical risk factor[76].

Presence of ulna fracture

Distal radius metaphyseal fractures with associated ulna fractures had a higher redisplacement rate than distal radius fractures without an associated ulna fracture. The presence of an ulna fracture is therefore a significant predictor of redisplacement in this study.

The role of associated ulna fracture on redisplacement has been described. Several authors found the presence of an ulna fracture a significant factor of redisplacement while others did not. Hang et al found the presence of an ipsilateral ulna fracture to be a significant clinical risk factor for redisplacement[76].Similarly,Zamzam et al[14] and Bohm et al[55]identified presence of ulna fracture as a significant factor. According to Gibbons et al[63] isolated fractures of the distal radius were more unstable and therefore more likely to reangulate than with a concurrent ulna fracture. However, Alemdaroglu et al[71] did not find any significant contribution of an ulna fracture to redisplacement.

Type of anaesthesia used as a risk factor for redisplacement

The type of anaesthesia used was light sedation or no anaesthesia at all. This study found that the rate of redisplacement between the two groups was similar(27.8% and 27.2%).Therefore this study did not find any significant influence of light sedation or no anaesthesia on the redisplacement rate. However, other modes of anaesthesia such as general anaesthesia and hematoma block were not considered in this study as they are rarely done in this study setting.

Zamzam et al suggested that completely displaced fractures be manipulated under general anaesthesia.This allows the surgeon to concentrate on the reduction and easy conversion to operative management if reduction fails.[13]

Type of cast applied in relation to redisplacement

In this study, either a short arm cast(below elbow cast) or a long arm cast were used. Most of the fractures were immobilized in a short arm cast with only 20.7% of the study population immobilized in a long arm cast. The rate of redisplacement was higher in the group immobilized in a short arm cast. However, this may not be significant as long arm cast was mainly done for children aged between four and eight years old.Majority of the children in this study were aged between nine and thirteen years and this is the same age group with most redisplacements and their fractures were immobilized in a short arm cast.

Whether to apply a short arm or a long arm cast remains controversial[52,53]. Bohm et al in their study on below and above elbow plaster casts for distal forearm fractures in children concluded that a short arm cast would suffice except for a toddler who is likely to wiggle out of the cast[54,55].Chess et al found out that short arm casts are highly effective in maintaining reduction of all fracture patterns[52].

Bohm et al,in their comparison between short and long arm casts found no significant difference between them[55].The complication rates were similar in both groups.

Webb et al in their study on comparison of long and short arm plaster casts for displaced fractures of the distal forearm in children found no significant difference in demographic, fracture characteristics,mechanism of injury and cast index during treatment[53].The fractures that lost reduction had higher cast indices pointing to poor technique rather than the type of cast[53].

Accuracy of reduction in relation to redisplacement

The group that did not redisplace had a more anatomical reduction than the group that redisplaced. According to this study, the closer the reduction is to anatomical reduction the less likely it is to redisplace.It was noted that some fractures in the group that did not redisplace had some degree of redisplacement after casting though this remained within the acceptable reduction. They were therefore classified as undisplaced and remanipulation was not necessary.

Most authors concur that the accuracy of reduction significantly influences the rate of redisplacement. The accuracy of reduction is age related. Noonan and Price et al[75] concluded that children less that 9 years of age are likely to heal with complete translation and angulation of less than 15^0.He further found that children older than 9 years with completely translated fractures and more than 10^0 of angulation were likely to result into malunion.Bae et al[69] noted that the closer to anatomical reduction the fracture is, the lesser the likelihood to displace.

According to Hang et al,in their retrospective study of 48 redisplaced fractures, failure to achieve anatomical reduction was a significant factor for fracture redisplacement[76].

11.0 CONCLUSION

Displaced complete distal radius metaphyseal fracture is the most common fracture pattern observed among the displaced fractures,followed by greenstick and bayonet apposition fractures. The total rate of redisplacement of displaced distal radius metaphyseal fractures in skeletally immature patients is 27.6%.

The significant factors for predicting the likelihood of redisplacement of distal radius fractures in children are the duration of time from injury to treatment, the mechanism of injury,the fracture pattern, and the initial displacement, presence of an ulna fracture and the accuracy of reduction.

The longer the fracture stays before reduction the higher the likelihood of redisplacement. Fractures sustained through road traffic accidents and fall from heights are more likely to redisplace due to higher amount of energies involved.
Bayonet apposition fracture are more likely to redisplace than other displaced fracture types. The more displaced fractures before reduction have a higher chance of redisplacement. The presence of an ulna fracture increases the likelihood of redisplacement and finally the closer to anatomical reduction a fracture is the less likely it is to redisplace.

The patients age, gender, type of anaesthesia and the type of cast used do not influence the rate of displacement of distal radius fracture in children.

12.0 RECOMMENDATIONS

It is important to emphasize on the need for immediate post reduction radiographs to confirm the accuracy of reduction.

The plaster technicians, general practitioners, residents and surgeons need ensure that a check radiograph is done two weeks post reduction to detect redisplacement before malunion occurs.

Reduction of fractures in children should be done promptly as delayed closed reduction has a higher rate of redisplacement.

There is a significant risk of redisplacement in completely displaced distal radius fractures in this study population. Prophylactic pinning is recommended for such fractures.

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APPENDICES

APPENDIX 1: CONSENT INFORMATION FORM FOR PARENTS AND GUARDIANS

Title of the study; Redisplacement Factors for Paediatric Distal Radius Fracture Treated by Cast Immobilization

Principal investigator: Dr. James Muoki

Introduction

This study seeks to find out the factors influencing redisplacement (bone slipping out of its normal healing position) of broken forearm near the wrist in children. The study will help health care givers find a better way of treating the broken bone or prevent the bone 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 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. James Muoki

P.O. 27263-00100 Nairobi, Kenya

Mobile 0721416565 or

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

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

Mkuu wa uchunguzi: Dr. Muoki James

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,jinsia yake na jinsi alivyoumia.Mchunguzi mkuu au wasaidizi wake watauangalia mkono 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 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:

Dkt. James Muoki

S.L.P 27263-00100 Nairobi,

Kenya. Simu 0721416565 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 5: ASSENT INFORMATION DOCUMENT FOR MINORS

Title of the study: Redisplacement Risk Factors for Skeletally immature Distal Radius metaphyseal Fracture Treated by Cast Immobilization

Principal investigator: Dr. James Muoki

Introduction

This study seeks to find out the factors influencing redisplacement (bone slipping out of its normal healing position) of broken forearm near the wrist. 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. James Muoki

P.O. 27263-00100 Nairobi, Kenya.

Mobile 0721416565 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.Muoki James

Utangulizi

Utafiti huu unataka kujua kuhusu kuvunjika kwa mkono 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:

Dkt. James Muoki

S.L.P 27263-00100 Nairobi, Kenya.

Simu 0721416565 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 10.The investigators will help you through questions 3 to 10

Patient initials …………………………Age (years)………………………

Gender (M/F) ……….........

1. When did you injure your forearm? (Write number of days)

   ………………………………………………………………………………………

2. How did you injure your forearm?
   - o Fell while playing
   - o Road traffic accident
   - o Fell from height
   - o assaulted

3. What is the fracture pattern? (Tick appropriately)
   - o Torus
   - o Greenstick
   - o Complete
   - o Bayonette apposition
   - o Presence of ulna fracture

4. What is the initial displacement(before casting?)
   - Angulation in coronal plane (degrees)………..
   - Angulation in sagittal plane (degrees)……….
   - Cortical translation ………. %

5. Is there an ulna fracture?
   - o Yes
   - o No

6. What is the ulna fracture pattern?
   - o Metaphyseal
   - o Physeal
   - o Ulna styloid

7. What was the type of anaesthesia given?

- No anesthesia
- Local anaesthesia
- Regional anaesthesia
- Intravenous sedation
- General anesthesia

8. What is the type of cast applied?

- Long arm cast(above elbow)
- Short arm cast(below elbow)

9. What is the displacement immediately post cast application?

(Measurement from the check X-ray)

- Angulation in coronal plane(degrees)…………
- Angulation in sagittal plane (degrees)…………
- Cortical translation (%)…………………………%

10. What is the displacement two weeks after cast application?

(Measurement from check X-ray done two weeks post casting)

- Angulation in coronal plane (degrees)…………….
- Angulation in sagittal plane (degrees)…………….
- Cortical contact (%)………………………………

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 9 na pia Mtafiti atakusaidia.

Jina lako kwa ufupi ………………………Umri(miaka)………………………

Jinsia (Mvulana/Msichana) ……….........

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

2. Je,uliumia vipi?(chagua)

   - o Kuanguka nikicheza
   - o Ajali ya barabara
   - o Kuanguka kutoka juu ya mti au nyumba
   - o kupigwa

3. Aina ya Mvunjiko ni ipi? (Mtafiti atakusaidia kujibu)

   - o Torus
   - o Greenstick
   - o Complete
   - o Bayonette apposition
   - o Presence of ulna fracture

4. Mfupa umewachana kivipi kabla ya kufungwa plasta? (mtafiti atakusaidia kujibu)

   - Angulation in coronal plane (degrees)………..
   - Angulation in sagittal plane (degrees)……….
   - Cortical translation (%) ………. %

5. Je,kuna mvunjiko wa mfupa wa ulna?

   - o Ndio
   - o La

6.Je,mvunjiko wa ulna ni upi? (mtafiti utakusaidia kujibu)

   - o Metaphyseal
   - o Physeal
   - o Ulna styloid

7. Je,madaktari walitumia dawa gani ya uchungu?(mtafiti atakusaidia kujibu)

   - o No anesthesia

- Local anaesthesia
- Regional anaesthesia
- Intravenous sedation
- General anesthesia

8. Je, ulifungwa kwa plaster ipi? (mtafiti atakusaidia kujibu)
    - Long arm cast(above elbow)
    - Short arm cast(below elbow)

9.Je,mfupa umewachana vipi baada ya kufungwa kwa plasta?Mtafiti atakusaidia kujibu)

(Vipimo vya X-ray)

- Angulation in coronal plane (degrees)…………
- Angulation in sagittal plane (degrees)…………
- Cortical translation (%)…………………………%

10. Je,mfupa umewachana vipi baada ya wiki mbili?

(Vipimo vya X-ray wiki mbili baada ya kufungwa plasta)

- Angulation in coronal plane (degrees)…………….
- Angulation in sagittal plane (degrees)…………….
- Cortical contact (%)………………………………

MWISHO

APPENDIX 11: STUDY BUDGET

ITEM	**COST(in KHz)**
Research fees (KNH/ERC)	2500
Stationary, printing, binding	20000
Statistician, research assistants	45000
Communication	5000
Contingencies	15000
TOTAL	**87500**

This research was funded by the principal researcher.

APPENDIX 12: KNH/UON-ERC APPROVAL

KNH/UON-ERC

KENYATTA NATIONAL HOSPITAL APPROVED 23 DEC 2016 KNH/UoN-ERC P.O. Box 20723-00202 NRB.

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Ref: KNH-ERC/A/488

23rd December 2016

Dr. James Kyalo Muoki
Reg. No.H58/82350/2012
Dept.of Orthopaedic Surgery
School of Medicine
College of Health Sciences
University of Nairobi

Dear Dr. Kyalo

REVISED RESEARCH PROPOSAL – REDISPLACMENT RISK FACTORS FOR SKELETALLY IMMATURE DISTAL RADIUS METAPHYSEAL FRACTURES TREATED BY CAST IMMOBILIZATION IN KENYATTA NATIONAL HOSPITAL (P647/09/2016)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH- UoN ERC) has reviewed and **approved** your above revised proposal. The approval period is from 23rd December 2016 – 22nd December 2017.

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) 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*).
f) Clearance for export of biological specimens must be obtained from KNH- UoN ERC for each batch of shipment.

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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.

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 Deputy Director, CS, KNH
The Chairperson, KNH- UoN ERC
The Assistant Director, Health Information, KNH
The Dean, School of Medicine, UoN
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