Patient based outcome after *in situ* percutaneous fixation of slipped upper femoral epiphysis

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of

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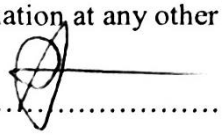
Declaration

I Dr T.E Phiri declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Orthopaedic Surgery at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



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08 October 2021

Dedication

This research report is dedicated to my family as a whole but most importantly to my wife, Mrs Itumeleng Phiri, for her patience, understanding, emotional and psychological support during this project. It is also dedicated to my children, Boikanyo and Odirile, for the family times I never got to spend with them.

Presentations and publications arising from the research project

The results of this study were presented at the South African Orthopaedic Association 65th Annual Congress, 2-6 September 2019, Durban ICC, South Africa. A poster presentation was presented at the Wits Research Day 2019.

Abstract

Background:

Percutaneous *in situ* fixation with a single screw is regarded as safe and remains the gold standard of treatment for Slipped Upper Femoral Epiphysis (SUFE). However, reliance is placed on subsequent remodelling of the femoral neck. Healing in a non-anatomic position predisposes the patient to femoroacetabular impingement (FAI) and degenerative arthritis of the hip. Consequently, some surgeons advocate for surgical hip dislocation and reduction of severe acute SUFE. The aim of this study was to assess patient-based outcomes after *in situ* pinning. The hypothesis is that our patients remodel adequately and function well after *in situ* pinning.

Methods:

Twenty-six patients (36 hips) with different severity of SUFE that were treated at our institution between January 2011 and December 2016 were included in our retrospective study. Patients with less than two years' follow-up and those without prior radiographs were excluded. Hips were radiologically classified into three groups; mild SUFE (13 hips), moderate SUFE (12 hips), severe SUFE (11 hips) and clinically into stable (31 hips) and unstable SUFE (5 hips). Outcome measures included modified Harris Hip Score and Visual Analogue Pain Score.

Results:

There were no cases of avascular necrosis (0%) in both mild and moderate stable slips treated with *in situ* pinning. Only one case of avascular necrosis (AVN) was reported out of eleven severe slips (9.1%). This is significantly lower than the results of the previous studies that evaluated *in situ* pinning in severe slips. In addition, there was one case of FAI that developed in one of the eleven slips (9.1%). There were no cases of chondrolysis reported. The overall complication rate for AVN and FAI after *in situ* pinning was 2.78%.

Conclusion

Our results suggest that in our population *in situ* percutaneous pinning is safe with low complication rates. High patient satisfaction in terms of pain and function suggests that remodelling is effective, even for severe slips.

Acknowledgements

I would like to thank God for the strength and guidance I received during this research project.

I would also like to express my sincere gratitude towards my supervisors, Prof Robertson and Dr Simmons, for their guidance and patience when I was struggling, for their understanding when I was frustrated and most importantly for the precious time I took from their families. May the Great Almighty God bless them!

I would also like to thank Dr Maxwell Jingo and Dr Brenda Milner for the support and input I received during this project.

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Nomenclature

AVN	Avascular necrosis / osteonecrosis
BMI	Body Mass Index
CHBAH	Chris Hani Baragwanath Academic Hospital
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
FAI	Femoral-Acetabula Impingement
MHHS	Modified Harris Hip Score
ROM	Range of motion
SD	Standard Deviation
SUFE	Slipped Upper Femoral Epiphysis
THR	Total Hip Replacement
VAS	Visual Analogue Score
WHO	World Health Organisation
WITS	University of the Witwatersrand

CHAPTER 1

1.1 INTRODUCTION AND LITERATURE REVIEW

Slipped Upper Femoral Epiphysis (SUFE) is a disorder of the hip that is commonly seen in adolescent patients with a postero-inferior displacement of the femoral head relative to the neck[1]. This definition is inaccurate and misleading as the epiphysis stays in the acetabulum and the neck of the femur displaces anterosuperioly[2] (see Figure 1.1).

Figure 1.1: Pelvis x-ray showing typical unilateral SUFE of the left hip.

There is a higher incidence of SUFE in adolescent boys compared to girls (1.5: 1) and black children are four times more affected than white children[3]. In the international study of 1600 patients, Loder et al. reported an average age of 12 ± 1.5 years for girls and 13.5 ± 1.7 years for boys[4]. It is very unusual for children under the age of ten years to present with SUFE and if they do endocrine, causes should be excluded[5].

Most children (80%) present with unilateral pathology with the left hip more commonly involved than the right. Only 10 - 20% patients with SUFE will have bilateral hip involvement at presentation; however, 80% will develop bilateral pathology over time[6].

In most cases, the aetiology of slipped upper femoral epiphysis is unknown. Irrespective of the underlying cause, the end stage of the pathology is due to the weak physis that fails to withstand the shear forces across it. Inability to withstand stresses due to endocrine diseases[7] (e.g. hypothyroidism) and increased mechanical stresses such as obesity have been postulated to contributing to relative weakness of the physis in patients with SUFE[8].

The importance of blood supply to the epiphysis cannot be over-emphasised. The superior retinacular artery can be disrupted during reduction of the epiphysis resulting in avascular

necrosis (AVN)[9], however, disruption of blood flow can occur even before reduction is done. Maeda et al. reported on the results of angiography performed on 12 patients with SUFE (seven stable and five unstable SUFEs) to assess blood filling in different severity of slips. Blood filling of the retinacular artery was recorded in all seven stable SUFEs whereas only two unstable SUFEs had blood filling. The other three unstable slips had blood filling after reduction of the slip. The study concluded that unstable SUFE have high risk of AVN due to disruption of the blood supply[9].

Clinically, the patient with SUFE usually presents with groin, thigh or knee pain and examination demonstrates external rotation foot progression during walking. Passive flexion of the hip results in obligatory external rotation of the hip[1].

Traditionally, SUFE has been classified into three groups (acute, chronic and acute-on-chronic) based on the duration of symptoms. This classification has not been found to be of prognostic relevance, as it does not incorporate stability of the slip. In 1993, Loder et al. published a new practical and clinically relevant classification based on physeal stability (stable and unstable SUFE)[10]. With a stable slip, the child can walk with or without the aid of crutches whereas in an unstable slip the child is not able to walk even with crutches. The classification is useful in predicting the risk of AVN of the femoral head. According to Loder et al., stable slips were found to have a lower incidence (0%) of AVN compared to unstable slips (47%)[10].

The Southwick classification measures the severity of the slip based on the femoral head-shaft angle. This is measured on the frog-leg lateral x-ray view. The angle calculated on the normal hip is subtracted from the head-shaft angle of the pathological hip[11]. Mild SUFE is the neck-shaft angle < 30°, moderate SUFE = 30 - 50°, severe SUFE > 50°.

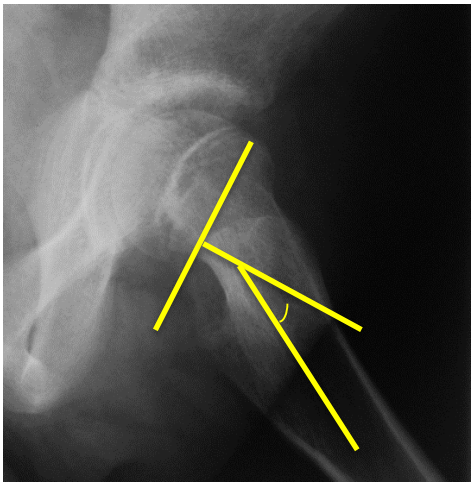

Figure 1.2: Frog leg lateral x-ray view showing measurement of Southwick neck-shaft angle.

The natural history of untreated SUFE is a progressive slippage and subsequent deterioration of the hip function that correlates with initial severity of the deformity[12]. Increased severity at presentation has been associated with a prolonged duration of symptoms and complications[13].

Weinstein et al. reviewed 124 patients (155 hips) with slipped upper femoral epiphysis 21 years after initial presentation. Only 142 hips were included in this retrospective study and were classified into three groups, mild SUFE (42%), moderate (32%) and severe SUFE (36%). Of these 142 hips, 25% had symptomatic treatment, 30% had Spica cast treatment, 24% were treated by in situ pinning and 20% were treated with osteotomy. The development of osteoarthritis worsened with increasing severity of slip and when reduction was done[13]. However, the natural history of untreated SUFE suggests that the patients will do well until the fifth decade of life[12].

Most patients with SUFE will ultimately develop osteoarthritis. However, Weinstein et al. noted that the presence of AVN had a far worse outcome than when patients did not have AVN[12].

Although AVN and chondrolysis are the most encountered and feared complications, treatment of severe unstable slip by *in situ* pinning often leaves the patient with residual femoral head-neck deformity due to lack of reduction[14]. This non-anatomic head-neck deformity may result in impingement of the femoral neck on the acetabular rim (femoral-acetabular impingement) which may lead to early onset of osteoarthritis due to acetabular cartilage damage in the long term[15, 30]. This will subsequently lead to decreased hip motion[16] and for this reason, some authors[16, 17] advocate surgical hip dislocation and reduction of the epiphysis (modified Dunn procedure) as a treatment method for severe slips. This treatment allows for the correction of the femoral head-neck deformity and reduction of the epiphysis and therefore delays early development of degenerative changes of the hip[16].

The treatment of slipped upper femoral epiphysis is controversial, historically the use of options like bone graft and casting has been unsuccessful. The current treatment options are percutaneous *in situ* pinning and surgical hip dislocation and reduction of the epiphysis (modified Dunn procedure). Traditionally, percutaneous *in situ* pinning has been the gold standard of treatment for both stable and unstable SUFE; however, there is concern about the residual femoral-neck deformity observed with this treatment in severe slips. With no reduction during *in situ* pinning, the hip is left in non-anatomic position and this poses a risk of femoral-acetabular impingement (FAI) in the long term. Long-term studies have shown that with time, the risk of impingement diminishes due to metaphyseal remodelling and if impingement occurs, it has minimal clinical consequences[18].

The original Dunn procedure (subcapital correction osteotomy) has been able to fully correct the femoral neck deformity in patients with severe SUFE but the rate of AVN (17%) associated with this technique is high[19]. In 1996, Leunig et al. described a modification of Dunn's procedure in which subcapital realignment is combined with surgical hip dislocation (Ganz technique). The hip dislocation allows for reduction of the epiphysis without compromising the epiphyseal blood supply. Of the 30 hips treated with this procedure between 1996 and 2005, none of the patients developed AVN after an average follow-up of four years from the time of surgery[20].

Ziebarth et al. reproduced similar results after using the same procedure (modified Dunn procedure) in 40 patients with SUFE treated at two institutions. Twelve of the 40 patients were classified as unstable SUFEs and the rest were stable. None of these patients had developed AVN at three years' follow-ups, only one patient developed residual impingement for which revision was done. Three other patients had screw breakage as complications[17].Although the results of these two studies[17,20] are promising the short duration of follow-up and the lack of a control group does not favour this technique over percutaneous *in situ* pinning.

For this reason, Ziebarth et al. decided to review 43 patients with SUFE at ten years' follow-up but 70% of these patients were included in the previous study. The authors reported no incidence of AVN in this cohort and no hip was converted to total hip arthroplasty (THA) because of osteoarthritis (OA) however, six patients had persistent impingement deformity[21]. A major limitation of this study is that all the hips included in this study were treated with the modified Dunn procedure irrespective of stability or severity of slip. Only five patients (12%) had unstable slips in the group the rest were stable slips and among the unstable slips, the majority (63%) were classified as moderate slip (Southwick classification). Stable slips have been shown to have an excellent outcome even when treated with *in situ* pinning therefore the promising results reflected by Ziebarth et al. could be due to the high numbers of moderate slips (63%) and mild slips (23%) included in their study. The controversy stems from the outcome of treatment of severe unstable slips and not mild or moderate slips.

In 2013, Sankar et al. published the results of 27 patients with unstable SUFE (largest series of unstable slips according to the author) who were treated at five different institutions by fellowship trained paediatric orthopaedic surgeons. Patients had an average of one-year follow-up. Seven of the 27 patients (26%) developed AVN at follow-up and four patients (14%) had broken implants for which revision was done. The authors concluded that, although this surgical technique can restore functional anatomy of the hip and possibly prevent early degenerative changes, this technique should be considered with caution because of its complexity and high rate of AVN (26%)[22].

When comparing these two treatment methods (pinning *in situ* and modified Dunn procedure), Souder et al. did not find any significant difference in terms of outcome (osteonecrosis) after treating unstable SUFEs. Three of the seven unstable slips treated with *in situ* pinning developed AVN (43%) while two of the seven unstable slips treated with modified Dunn procedure developed AVN (29%). However, patients with stable SUFEs had better outcome and no AVN when treated with *in situ* pinning (0%) compared to treatment with modified Dunn procedure (20%)[23].

Carney et al. reported on the outcome of 124 patients (155 hips) with different severity of SUFE that had follow-up after 41 years. Only 19 patients (12%) who had severe slips and were treated with reduction developed AVN and 25 patients (16%) developed chondrolysis as a complication. About 70% of patients had no complications 41 years after presentation. The authors concluded that treatment of SUFE with *in situ* pinning provides the best long-term outcome with low rates of AVN regardless of severity of slip[24].

In their retrospective study, Tokmakova et al. reported a high rate of AVN (58%) in 21 of the 36 unstable SUFE patients that were treated with reduction of the epiphysis. Unstable slips that were treated with *in situ* pinning had low rate of AVN[25]. In a local retrospective study published in 2009, Nortje et al. also reported AVN (10%) only in patients with severe unstable slips treated with *in situ* pinning using single screw[26].

Many publications[1,13,14,23,24] with long-term results favours *in situ* pinning as a treatment of choice for SUFE regardless of severity of the slip. Surgical hip dislocation and reduction of the epiphysis has shown promising results however there is no long-term outcome studies so far to support this treatment.

Several adult patient reported outcome scores have been used in paediatric patients with hip pathologies without validated evidence in the paediatric population[27]. The original Harris hip score was used to assess pain, physical activity and range of motion (ROM) in arthritic patients undergoing total hip replacement (THR). Due to high inter-observer variability, the range of motion measurements done by the clinician were excluded in order to modify the original score and this leaves only the patient based questionnaires in the modified score[28]. The modified Harris hip score consists of 100 points (0 – 100), a score < 70 indicates a poor outcome, 70 – 79, a fair outcome, 80 – 89, a good outcome and a score of 90 -100, an excellent outcome.

Patients' health reported outcomes are strongly becoming a vital research tool to assess the outcome of surgical treatment[29]. Currently there is no evidence that validates the use of any hip score in paediatric patients[27]. However, Escott et al. used the modified Harris hip score in their retrospective study as one of the measurement tools to evaluate patient-reported outcome of SUFE after *in situ* pinning[30].

The purpose of this study is to evaluate the patient-based outcome of SUFE patients treated with *in situ* pinning at our institution. Based on the outcome, we would determine if our current treatment protocol is acceptable or if it needs to be modified to include surgical reduction of the epiphysis in selected cases.

1.2 Relevance of the study

Anecdotally it has been our experience that SUFE patients treated with *in situ* pinning are functioning well and are pain free however, this hypothesis has not been tested.

1.3 The Aim of the study

To assess patient based outcomes following *in situ* percutaneous fixation of SUFE patients treated at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) and Chris Hani Baragwanath Academic Hospital (CHBAH).

1.4 Study Objectives

- To determine the overall patient's satisfaction in terms of pain.
- To determine patient's satisfaction in terms of limitation of daily living activities after *in situ* percutaneous fixation.
- To relate the outcome to the severity of the slip on presenting x-rays.

CHAPTER 2

2. METHODOLOGY

2.1 Study Design

This was a retrospective study with a prospective recall, which included both male and female adolescent patients with SUFE treated at CMJAH and CHBAH between January 2011 and December 2016. Ethics clearance was obtained from the Human Research Ethics Committee (HREC) (Medical) of the University of the Witwatersrand. The HREC (Medial) clearance number is M170365 (see Appendix A).

2.2 Materials and Methods

Patients with slipped upper femoral epiphysis treated at CMJAH and CHBAH between 2011 and 2016 were identified from theatre operation register and were recalled for follow-up. The purpose of the study was explained to both the parent and the child. The information sheet regarding the study was provided to the parents to read before signing the consent. Parent consent and child assent forms were signed, none of the patients was forced to participate in the study and patients were allowed to withdraw at any time when they felt they wanted to do so.

Measurement tools were (see Appendix B and C);

- Radiological measurement on initial x-ray
    - Southwick angle
- Patient based questionnaire
    - Modified Harris hip score (as used by Escott et al.[30] and Sharma et al.[31]).
        - Excellent: 90 – 100
        - Good: 80 – 89
        - Fair: 70 – 79
        - Poor: < 70
- Visual analogue pain score (VAS)

- Wong-Baker visual analogue score[32] used with permission (see Appendix C and D).

2.3 Selection Criteria

Inclusion criterion:

- All patients treated by *in situ* pinning at CMJAH and CHBAH between 01 January 2011 and 31 December 2016.

Exclusion criterion:

- Patients with less than two years follow up since surgery; this ensures adequate time for remodelling of the epiphysis.
- Inadequate initial x-rays / CT scan.
- Patients referred with pre-existing complications from prior treatment received.
- Patients with avascular necrosis on initial x-rays.

2.4 Data Collection

The data of SUFE patients who were operated on between January 2011 and December 2016 were collected from a surgical register. Patients were called for a follow-up visit, consent and assent forms were signed by parents and patients, respectively. Patients were interviewed in terms of pain and functional capacity and the measurement scores were completed. The hip function was examined and scored by the primary investigator. Patients were allocated unique study numbers for anonymity. Patients were not subjected to pain or radiation; radiographs used during the study were obtained pre-operation and immediately post-operation. No new radiographs were done for the purpose of this research study. Two patients who were not able to visit for a follow-up were interviewed over the phone.

2.5 Data Analysis

The data were analysed using descriptive statistics and are represented in the form of bar graphs and Tables. The raw data were also entered in the Microsoft excel and analysed using Stata version 15.0. The first objective was to determine the overall patients' satisfaction in terms of

pain. The second objective was to determine patients' satisfaction in terms of limitation of daily living activities after *in situ* pinning. The third objective was to relate the outcome to severity of initial slip.

The following variables were included in the analysis:

- Age
- Gender
- BMI
- Hip involved
- Pain score
- Modified HHS

Three statistical tests were performed to evaluate the relationship between severity of slip and patient's outcome. A p-value < 0.05 was considered statistically significant.

- Chi-square test: was used to test correlation between two categorical variables (severity of slip and pain as well as severity of slip and functional outcome).
- Kruskal-Wallis test: was used to compare the three groups in terms of functional outcome.
- Spearman test was used to measure the relationship between BMI and severity of slip.

2.6 Limitations

Limitations of this study were its retrospective design, which resulted in many patients being lost to follow-up. As a result, the number of patients was relatively small and therefore there was no in-depth statistical analysis of data. There was no standardisation of treatment and record keeping. Registrars operated on some patients and some were operated on by consultants. Some patients' records had contact details and some did not have, rendering these patients untraceable. There is no validated hip score that is used in the paediatric population that we are aware of.

CHAPTER 3

3. RESULTS

Seventy-six (76) patients with SUFE were identified from the surgical registers. Forty-eight patients were lost to follow-up and two patients were excluded due to unavailable pre-operative x-rays and CT scan. Of the 26 patients included in the study, 16 patients were males (61.5%) and 10 patients were females (38.4%). Ten patients (38%) had bilateral hip involvement. The pathology was almost equally distributed between the right hip (19/36) and the left hip (17/36). Fifteen of the 26 patients (57.6%) in this study were classified according to World Health Organisation (WHO) as obese (BMI > 30kg/m²). The mean age at surgery was 12.7 years (range 9 to 15 years) and the mean follow-up was 3.3 years (2 to 7 years). It was noted that thirty-one of the 36 hips (86.1%) were stable and the remaining five hips were unstable on presentation.

The hips were classified radiologically into three groups according to Southwick neck-shaft angle; mild SUFE, moderate SUFE and severe SUFE (see Tables 3.1 – 3.3).

The first group (see Table 3.1) consisted of 13 mild SUFE (36%) with a mean age of 11.6 years (SD 0.96). All the hips in this group were clinically classified as stable. Patients in this group were mostly overweight with a mean BMI = 28.8kg/m². The mean pain score was 1.23 and the modified Harris hip score was 96.7.

Table 3.1: **Summary of statistical prevalence of Mild SUFE (*n* = 13)**

Variance	Mean	Standard Deviation (SD)	Minimum	Maximum
Age	11.61	0.960768	10	13
BMI	28.8	6.33706	17.8	37.5
Visual analogue pain score	1.23	1.012739	0	2
Modified HHS	96.73	3.399151	91.1	100

The second group consisted of 12 SUFE (33%) of moderate severity (see Table 3.2). All the hips in this group were classified as stable slip. The mean age was 13.08 years (SD 2.19) and most of the patients were obese with a mean BMI = 31.66 kg/m². The mean pain score was 2.16 and the modified HHS was 92.24.

Table 3.2: Summary of statistical prevalence of Moderate SUFE (*n* = 12)

Variance	Mean	Standard Deviation (SD)	Minimum	Maximum
Age	13.08	2.193309	10	17
BMI	31.66	6.529421	22	44.6
Visual analogue pain score	2.166	1.029857	0	4
Modified HHS	92.24	5.713693	82.5	100

The third group consisted of 11 severe SUFE (see Table 3.3), five of them were clinically classified as unstable slips and six of them were stable. The mean age was 13.08 years (SD 2.19) and patients in this group had normal weight according to WHO classification (BMI = 24.71kg/m²). The mean pain was 2.36 and the modified HHS was 87.89.

Table 3.3: Summary of statistical prevalence of Severe SUFE (*n* = 11)

Variance	Mean	Standard Deviation (SD)	Minimum	Maximum
Age	13.45	1.368476	12	15
BMI	24.71	6.272132	16.4	36
Visual analogue pain score	2.36	1.206045	0	4
Modified HHS	87.89	6.093842	79.2	100

As seen in the following Figure 3.1 there was deterioration of functional outcome (as measured by modified HHS) between the three groups.

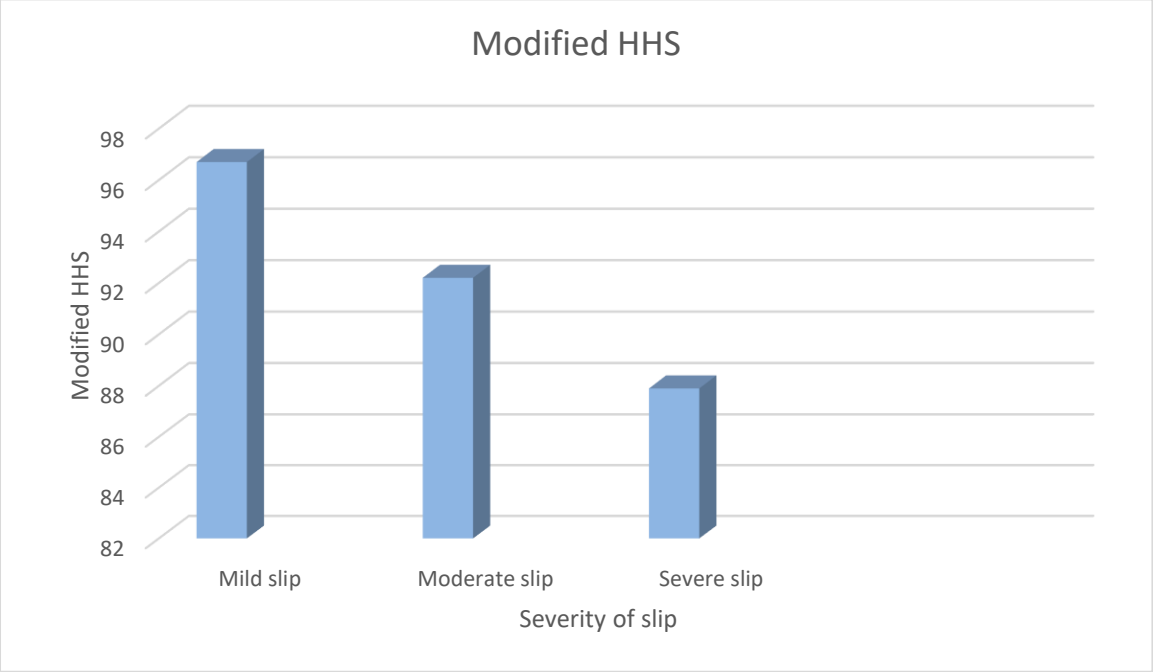

Figure 3.1: The relationship between severity of slip and functional outcome across the three groups (p = 0.003).

Patients with severe SUFE reported more pain than other two groups (see Figure 3.2). However, this was not statistically significant (p = 0.099).

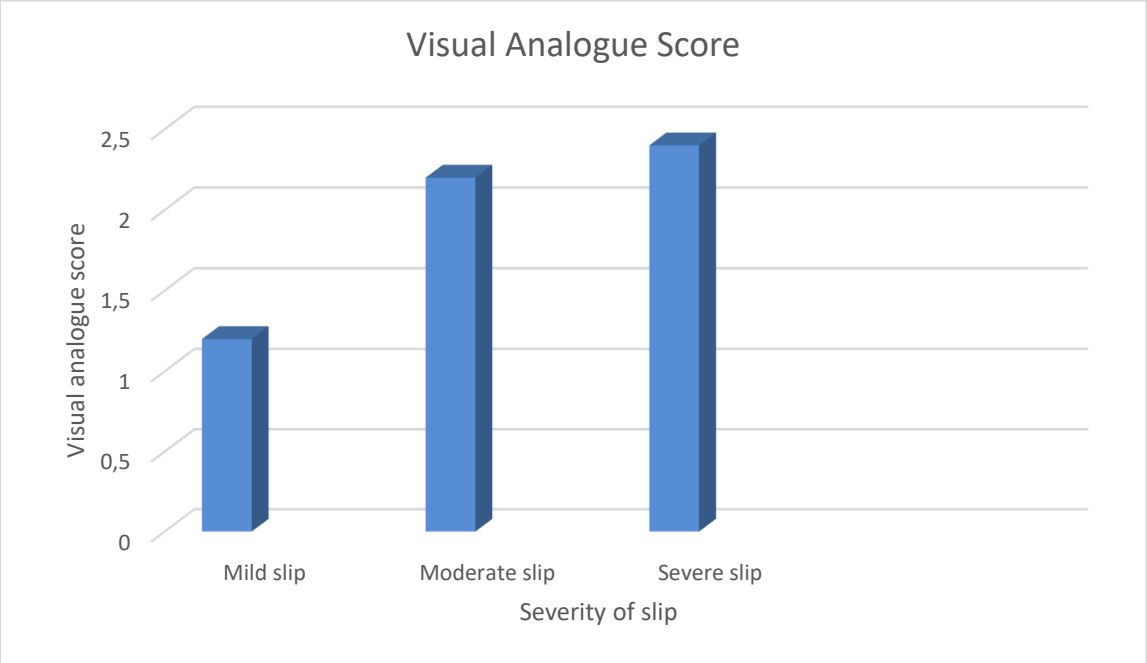

Figure 3.2: The relationship between severity of slip and pain (p = 0.994) across the three groups

The following table (see Table 3.4) shows a summary of statistical variance of the three groups (from mild to severe). There was a statistically significant difference between the three groups (see Figure 3.1) in terms of functional outcome (p = 0.003). The three groups did not show any statistically significant difference in terms of pain (p = 0.994) and BMI (p = 0.058).

Table 3.4: Summary of statistical variance of the three groups

Severity of slip	*n*	Age (mean)	BMI (mean)	Pain score (mean)	Modified HHS (mean)
Mild SUFE	13	11.6	28.8	1.23	96.73
Moderate SUFE	12	13.0	31.6	2.16	92.4
Severe SUFE	11	13.4	24.7	2.36	87.89
Mean (SD)		12.7(2.1)	28.3(6.5)	1.91(1.02)	92.3(5.7)
***P*-value**			0.058	0.994	0.003

The complications reported in this study were only observed in patients with severe and unstable slips (see Table 3.5). There were no complications reported in the mild and moderate SUFEs as well as severe stable slips treated with *in situ* pinning.

Table 3.5: Complications stratified by severity of SUFE (*n* = 36)

Severity of SUFE	*n*	Complications	Percentage (%)
Mild SUFE	13	0	0%
Moderate SUFE	12	0	0%
Severe SUFE	11	2	18.1%

The overall complication rate for AVN (one in 36 hips) and FAI (one in 36 hips) in this study is very low for both (2.78%). However, the rate of AVN and FAI in severe SUFE was 9% each (one in 11 slips). These two complications occurred in severe slips that were further classified as unstable according to Loder's classification.

CHAPTER 4

4. DISCUSSION

Several approaches for the treatment of SUFE have been described in the literature with different outcomes especially for acute severe slips (Southwick angle > 50°). As a result, some surgeons[20,21] currently advocate for open surgical hip dislocation and reduction of acute severe slip as opposed to the traditional method of treatment with *in situ* percutaneous pinning. The treatment protocol for SUFE patients at our institution has been *in situ* percutaneous pinning irrespective of severity of slip. Patients presenting with symptomatic deformity after remodelling of the metaphysis would be considered for surgical correction with Southwick intertrochanteric osteotomy. Anecdotally we have always assumed that there will be sufficient remodelling of the metaphysis and that these patients are satisfied in terms of pain and function after treatment but we have never tested this hypothesis. This study undertook to test this hypothesis by means of the patient reported outcome.

Our study included 26 patients (36 hips) with SUFE who underwent treatment with percutaneous *in situ* fixation with a single screw at our institution. From the 76 patients that were identified from the surgical registers forty-eight of them (63%) were lost to follow-up. Among those lost to follow-up 30 patients were not contactable (no telephone numbers in the file), twelve patients were from neighbouring countries, five patients from outside the Gauteng province refused to be part of the study and one died from a brain tumour.

The twenty-six patients included in this study were followed-up for a minimum of two years' post-surgery when the affected metaphysis had fully remodelled. None of these patients required an osteotomy to improve functional outcome including the patient that had impingement, as his symptoms were minimal (i.e. intermittent pain related to sports activities).

A mean with standard deviation of 12.7(2.1), 28.3(6.5), 1.91(1.02) and 92.3(5.7) was found for age, BMI, pain score and Modified HHS, respectively in our selected patients (see Table 3.4). Our study shows a male predominance over females with the ratio 1.6: 1. The average age at presentation was 12.1 years for girls and 12.9 years for boys. There were more black patients than other races (white, coloured and Indians) in our study. Lehmann et al. also reported a higher incidence of SUFE in black patients than other races (Hispanic and whites)[3]. However, in our study the high number of black patients could be the reflection of our population demographics.

Most of the patients (61.5%) had unilateral involvement of the hip with both right and left hip almost equally affected. This is different to published reports[1,3] in which the left hip is more commonly affected than the right.

Only ten of the 26 patients (38.4%) had bilateral hip involvement in our study, which is relatively lower than reported in the literature. Loder et al. reported that 50% of patients in their international multicentre retrospective study had bilateral hip involvement[4]. However, Aronsson et al.[8] reported a similar incidence (20-40%) of bilateral hip involvement to our study.

The results of our study show a statistically significant difference between the three groups in terms of functional outcome ($p = 0.003$). There was no significant difference in terms of pain ($p = 0.099$). The severe SUFE group had an inferior functional outcome (modified HHS = 87.9) compared to moderate SUFE (modified HHS = 92.4) and mild SUFE (modified HHS = 96.7).

However, the lower score (modified HHS = 87.9) in the severe SUFE group was regarded as a good outcome according to the interpretation used in the literature[28,30,31] and the mild and moderate SUFE groups had excellent outcomes. In their retrospective study Escott et al. used the same score (modified HHS) as a measure of patient based reported outcome of SUFE patients after *in situ* pinning[30].

Thirty-one of the 36 hips (86.1%) presented as stable slips and five hips (13.8%) were noted to be unstable on presentation. All the hips in the mild and moderate SUFE groups were stable and had excellent patients reported outcome. This supports the literature that hips with stable slips have excellent outcome and a low rate of avascular necrosis (0%) compared to the hips with unstable slips, which have high rate of avascular necrosis (47%)[10].

Twenty-four of the 26 patients (92%) were satisfied in terms of functional outcome and pain relief and would recommend the same treatment to other patients. Although our SUFE patients with severe slips were comfortable with daily living activities, two were not capable of performing sporting activities due to limited range of motion of the hip and pain. These two patients had AVN and FAI respectively. This suggests that the long-term functional outcome in our study was related to the complications rather than severity of the slip. In their retrospective study, Carney et al. reported that there was a correlation between the severity of slip and poor outcome at long term follow-up[12].

Fifteen of the 26 patients (57.6%) included in our study were obese according to the WHO classification (mean BMI > 30kg/m^2). These patients were observed in the mild and moderate SUFE groups compared to patients with normal weight (mean BMI = 24 kg/m^2) observed in the severe SUFE group. The mild and moderate groups had an excellent functional outcome irrespective of the higher BMI. Our study suggests that, although BMI is a risk factor for SUFE

it is not necessarily a clinical predictor of poor outcome (most patients with higher BMI had good outcome). This is contrary to the results published by Escott et al. (2015) who reported a better functional outcome of SUFE patients with low BMI than those with high BMI[30].

The patient that had AVN in our study was 12 years old at the time of presentation; he was obese with a BMI of 33.7 kg/m². He presented with a history of right hip pain for three weeks prior to a fall. He was unable to walk even with crutches (unstable SUFE) on presentation. Radiological investigations showed severe SUFE of the right hip on presentation (see Figure 4.1).

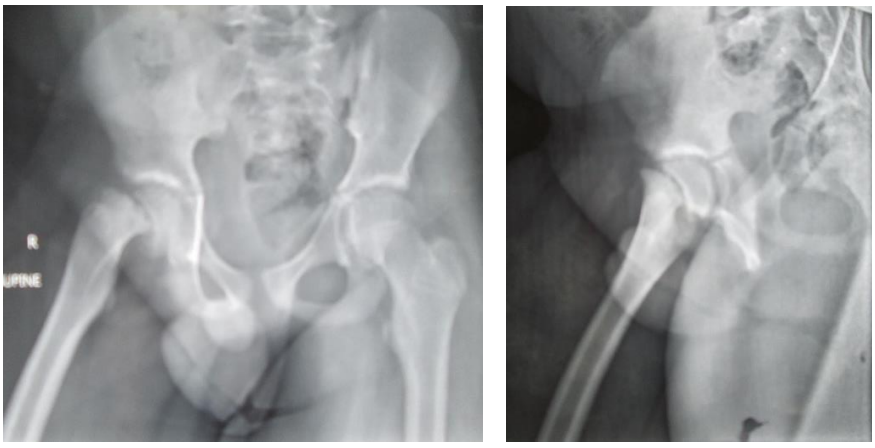

Figure 4.1: Pelvis and Frog leg lateral x-ray views showing severe SUFE of the right hip.

The right hip was treated with *in situ* percutaneous pinning and no reduction of the slip was attempted. However, there was an incidental reduction of the slip when the patient was moved from the ward bed to the operating table. The left hip was pinned prophylactically as the triradiated cartilage was still open. The patient developed AVN six months after *in situ* pinning (see Figure 4.2).

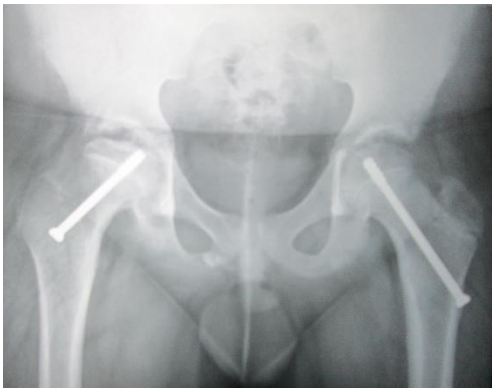

Figure 4.2: Pelvis x-ray showing bilateral pinning of slipped upper femoral epiphysis. The x-ray was done six months after surgery.

The screw was then removed from the right hip and the patient was referred to physiotherapy for range of motion exercises. The right hip AVN had worsened at two years' follow-up (see Figure 4.3). He was complaining of limited range of motion of the hip at the time of his last follow-up. The limb was ± 2 cm short compared to the contralateral limb. The patient was unable to participate in sports as he had a limited range of motion of the hip and the activity resulted in pain. The patient scored himself as four on the Wong-Baker visual analogue score (see Appendix C). He was otherwise coping well with activities of daily living. The patient was advised that THR would be a possibility, as a young adult should his symptoms progress and become severe.

Figure 4.3: Avascular necrosis of the right hip two years after *in situ* pinning. The prophylactic screw is shown on the left hip.

The second complication observed in our study was FAI. The patient was 15 years old when he first presented at our institution. His weight was normal (BMI = 24.8kg/m^2). He presented with a painful left hip following a fall during squatting exercises at a gym. He was unable to walk. The patient presented to the hospital immediately after the incident. Radiographs showed

SUFE of the left hip (see Figure 4.4) which was measured as severe on the frog leg lateral x-ray view.

Figure 4.4: Pelvis x-ray view showing SUFE of the left hip.

The patient was treated with *in situ* pinning of the left hip. Three years after initial presentation the patient started complaining of limited range of motion of the left hip, especially when squatting. However, he scored himself as two on the pain score. Radiographs repeated at six years' follow-up showed *in situ* pinning of the left hip and anterolateral metaphyseal bump suggestive of FAI (see Figure 4.5).

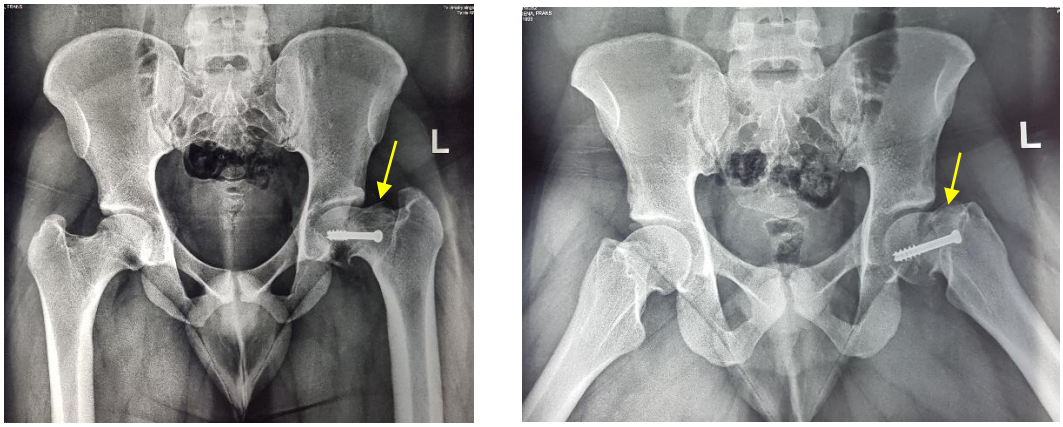

Figure 4.5: Pelvis and Frog leg lateral x-ray views showing FAI (arrow) of the left hip six years after *in situ* pinning.

The patient was examined for range of motion of the left hip, which was compared with range of motion of the right hip. The clinical findings are summarised in Table 4.1.

Table 4.1: Summary of clinical examination of the left and right hips

Motion	Right Hip	Left Hip
Flexion	110°	80°
Abduction	45°	30°
Adduction	30°	15°
Internal Rotation	30°	10°
External Rotation	40°	40°

Despite the discomfort with sports activities, the patient was satisfied with activities of daily living. Femoral-acetabular impingement has been shown to lead to early hip degenerative changes in SUFE patients. However, the functional outcome depends on remodelling of the metaphysis usually observed up to two years after initial presentation of the slip.

Boyer et al.[18] noted that the risk of impingement decreases with time because of metaphyseal remodelling. If FAI occurs, it does have minimal impact on the functional outcome.

Our study shows a low rate of AVN and FAI for severe SUFE (9%) after *in situ* pinning and the AVN rate for the whole study population was 2.78%. This is lower than the AVN rate (10-47%) reported in the literature[10,22,23] and much less than the AVN rate reported with modified Dunn procedure.

CHAPTER 5

5. CONCLUSION

Treatment of SUFE remains controversial especially for severe and unstable slips. However, the results of our study suggests that *in situ* percutaneous pinning using a single screw is still safe and effective and has a low rate of AVN (2.78%). This study suggests that there is a correlation between complications and long term functional outcome. The study also suggests that a high BMI does not necessarily predict a poor outcome. High patient satisfaction in terms of pain and functional capacity suggests that metaphyseal remodelling is effective and might delay early development of osteoarthritis due to impingement (FAI). We found that currently there is no evidence to support that surgical hip dislocation and reduction of the epiphysis provides a better long-term clinical outcome than *in situ* percutaneous pinning regardless of the severity of the slip. Until such evidence is published, pinning *in situ* remains the standard treatment in our institution for all SUFE cases.

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Appendix A: HREC (Medical) Ethics Clearance Certificate

R14/49 Dr Tshepang Phiri and Dr Simmons

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M170365

NAME: (Principal Investigator)	Dr Tshepang Phiri and Dr Simmons
DEPARTMENT:	Orthopaedics Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	Patient Based Outcome After in situ Percutaneous Fixation for Slipped Upper Femoral Epiphysis (SUFE)
DATE CONSIDERED:	31/03/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof A Robertson and Dr D Simmonds
APPROVED BY:	Professor P. Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	19/06/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004, 10th floor, Senate House/3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially review March and will therefore be due in the month of March each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date 24/07/2017

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix B: Modified Harris Hip Score

Please mark one choice for each topic

Pain:

……. None/ignores (44 points)

……. Slight, occasional, no compromise in activity (40 points)

……. Mild, no effect on ordinary activity, uses aspirin (30 points)

……. Moderate, tolerable, makes concessions, occasional codeine (30 points)

……. Marked, serious limitations (10 points)

……. Totally disabled (0 points)

Function: Gait

Limp:

……. None (11 points)

……. Slight (8 points)

……. Moderate (5 points)

……. Severe (0 points)

……. Unable to walk (0 points)

Support:

……. None (11 points)

……. Cane, long walks (7 points)

……. Cane, full time (5 points)

……. Crutch (4 points)

……. 2 Canes (2 points)

……. 2 Crutches (1 point)

……. Unable to walk (0 points)

Distance walked:

……. Unlimited (11 points)

……. 6 Blocks (8 points)

……. 2-3 Blocks (5 points)

……. Indoors only (2 points)

……. Bed and Chair (0 points)

Functional Activities:

Stairs:

……. Normally (4 points)

……. Normally with banister (2 points)

……. Any method (1 point)

……. Not able (0 points)

Socks / Shoes:

……. With ease (4 points)

……. With difficulty (2 points)

……. Unable (0 points)

Sitting:

……. Any chair, 1 hour (5 points)

……. High chair, ½ hour (3 points)

……. Unable to sit, ½ hour, any chair (0 points)

Public transportation:

……. Able to use public transportation (1 point)

……. Unable to use public transport (0 point)

Interpretation of the score:

Total score: 100 points

1. Score = 90-100 excellent
2. Score = 80-90 good results
3. Score = 70-80 fair results
4. Score < 70 poor results

Appendix C: Wong-Baker Visual Analogue Score

Appendix D: Letter of permission to use Wong-Baker Pain Score

Dear Tshepang Edison,

Thank you for contacting our foundation and completing the web form.

You have permission to use our scale in your research, without a licensing requirement or fee.

Please follow these four conditions:

- The information below is for your use only. We ask that you not share it with other unlicensed organizations.
- Use the authorized image of the scale provided below.
- Use the scale as the instructions indicate, without modifications.
- Do not use the scale for profit.

Here are the JPEGs of the Wong-Baker FACES® Pain Rating Scale in English for your use: English_Blue, English_Black

Appendix E: Data Collection Sheet

Name	
File number / Study number	
Age	
Race	
Gender	
BMI	
Wong – Baker Pain score	
Modified HHS	
Neck Shaft Angle: 1. Frog leg lateral view: Southwick angle 2. CT scan: Percentage slippage	
Hip involvement (Right or Left)	
Bilateral SUFE (Pin inserted 6 months later)	
Prophylactic pin (both pins inserted immediately)	
Reason for prophylactic pin e.g. open triradiated cartilage - endocrine causes - age < 10 years	
Co-morbidities	
Post-surgery complications e.g. AVN, Chondrolysis, FAI	
Pre-Operation mobility: Able to walk without crutches = stable slip Unable to walk even with crutches = unstable slip	