

DEVELOPMENTAL HIP DYSPLASIA

PREDICTING OUTCOME AND IMPLICATIONS FOR SECONDARY PROCEDURES

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Medicine in the branch of Orthopaedic Surgery.

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DECLARATION

I, Dr Gregory Bodley Firth, declare that this thesis is my own 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 this or any other university.

I acknowledge the assistance of DMSA (Specialists in Data Management and Statistical Analysis), a statistical company associated with the University of the Witwatersrand, for part of the statistical analysis done on the results.

This work is dedicated to Talitha my dear wife and my two children, who have endured endless hours spent
on this project.

Thank you.

PUBLICATIONS AND PRESENTATIONS ARISING FROM THE STUDY

1. South African Orthopaedic Association Annual Conference

Conference Presentation

Durban

September 2006

Title: Avascular Necrosis in DDH – Causative Factors and Outcomes

2. South African Orthopaedic Association Annual Conference

Conference Presentation

Johannesburg

September 2007

Title: A New Method to Predict the Outcome in DDH

ABSTRACT

A group of 133 hips with developmental dysplasia of the hip (DDH) are reviewed in the form of a clinical audit. The aim of the study is to determine the relevance of measuring the ossific nucleus centre edge angle (ONCEA) to determine if this measurement can be used to predict the final outcome and the need for a secondary procedure at an earlier age than currently determined. The ONCEA is defined as an approximation of the lowest centre edge angle within six months of removal of the Batchelor POP, following reduction (mean age 24.1 months). It is measured earlier than the centre edge angle (CEA), which is generally used from the age of five years.

The ONCEA was divided into three groups:

- Reduced ($\geq 10^\circ$) – Group A
- Mild subluxation (-9° to 9°) – Group B
- Severe subluxation ($\leq -10^\circ$) – Group C

The significance of the ONCEA was confirmed using the ONCEA/AI ratio, which was also divided into three groups:

- Reduced (>0.5) – Group A
- Mild subluxation (0 to 0.5) – Group B
- Severe subluxation (<0) – Group C

Outcome was assessed radiologically by way of the Severin score: In group C there were only 1/13 hips (8%) with an excellent result, in group B there were 20/44 hips (45%) with an excellent result and in group A there were 39/76 hips (51%) with an excellent result. Using Fisher's exact test, a statistically significant association was shown between each group and subsequent outcome ($p=0.001$). A significant result was also shown in a comparison of the three ONCEA groups using the McKay classification (a clinical outcome measurement).

The ONCEA/AI ratio was also used to include the degree of acetabular coverage. It had similar statistically significant results as described for the above ONCEA results, thus confirming the findings.

In conclusion, the ONCEA or ONCEA/AI ratio can be used at an early age (within six months following removal of POP after reduction, at a mean of 18 months of age) for two purposes:

1. To prognosticate the medium and long-term outcome of the patient.
2. To enable the clinician to determine whether a secondary procedure should be performed at an earlier age than usual. A prospective study will be necessary to confirm this.

ETHICS CLEARANCE NUMBER

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NOMENCLATURE

DDH – Developmental dysplasia of the hip

CDH – Congenital dislocation of the hip

CEA – Centre edge angle

AI – Acetabular index

ONCEA – Ossific nucleus centre edge angle (measured within six months of removing the POP, after formal reduction)

ONCEA $\geq 10^\circ$ (Reduced = Group A)

ONCEA -9° to 9° (Mild subluxation = Group B)

ONCEA $\leq -10^\circ$ (Severe subluxation = Group C)

ONCEA/AI > 0.5 (Reduced = Group A)

ONCEA/AI $0 - 0.5$ (Mild subluxation = Group B)

ONCEA/AI < 0 (Severe subluxation = Group C)

AVN – Avascular necrosis

POP – Plaster of Paris Cast

CT – Computed tomography

MRI – Magnetic resonance imaging

CHDD – Centre head distance discrepancy ratio

SAOA – South African Orthopaedic Association

1.0 INTRODUCTION

1.1 Definition and Relevance

The term congenital dislocation of the hip (CDH) has traditionally been used for a patient whose hip is dislocated from birth, resulting in dysplasia of the hip. The term ‘developmental dysplasia of the hip’ (DDH) is more encompassing and describes growth and differentiation, within embryonic, foetal and infantile periods.¹ DDH affects girls more commonly than boys (roughly 5:1) and occurs as a result of a congenital deficiency of contact of the femoral head with the acetabulum. This contact is essential for progressive normal development of the hip joint. The longer the dislocation is left, the more difficult reduction and subsequent acetabular remodelling becomes. It is imperative that a diagnosis is made as early as possible in order for a successful treatment regimen to be implemented that will ensure a located hip. This will result in the maximal potential for normal remodelling and development.

All the patients in this study underwent closed or open reduction, implying that they all had hips that were dislocated prior to treatment – congenitally dislocated hips with developmental dysplasia.

With good management the outcome is generally excellent, but if intervention is delayed or incorrect or complications occur (in particular avascular necrosis (AVN) of the femoral head or residual subluxation), the child can be left crippled for life or develop early debilitating osteoarthritis of the hip (late thirties in women and early fifties for men).²

This study is relevant as it explores a large group of patients with DDH never studied at this level in this region of Southern Africa before. It investigates the early role of the centre edge angle of Wiberg (CEA) called the ossific nucleus centre edge angle (ONCEA) and the acetabular index (AI) as predictors in the management and outcome of children with DDH.

One of the supervisors (AR) has noted in his clinical practice that once the patient has had the Batchelor POP removed, some hips drift into a subluxed position. The senior supervisor (AS) would encourage the clinician in this situation to wait and observe the patient. By doing this the patient is left to remodel her acetabulum without further intervention. The point at which one can wait and at which one should act was not specifically noted early on after reduction. Serial radiographs were taken, showing the development of the acetabulum. A secondary procedure was performed at the age of five years if the AI was abnormal ($>30^\circ$ at the age of about five years). The aim in this study was to try to predict the outcome of these patients at an early age using a simple measurement – the ONCEA or ONCEA/AI.

1.2 Background

This study concerns children with developmental dysplasia of the hip (DDH), which affects about 1:1000 children in first world countries. Its incidence is not precisely known in South Africa. The majority of patients were referred to AS with no prior management. A minority were treated by other orthopaedic surgeons (partially or completely) before referral. This latter referral was done either because the patient had moved to Johannesburg or the treating orthopaedic surgeon felt he was not experienced enough to continue the often complicated course of these children.

The patients came from a wide geographical area, including the greater Johannesburg and Pretoria regions, areas of Limpopo province, areas of the Eastern Cape and Cape Town. Some came from even further afield: Namibia, Angola, Zimbabwe and Mozambique. A few patients had recently immigrated from Europe (United Kingdom and Portugal).

The population base was from an extremely large area geographically, representing a broad sample of the pathology being investigated, but probably encompassing a large percentage of complicated cases from the region.

Motivation for this study comes from this large series of cases treated by the senior supervisor, AS, over a thirty-year period. It has only been made possible by his thorough record-keeping and follow-up. Roughly 300 patients' files were available.

Given the vast nature of the subject, only acetabular development will be explored in detail, as it relates to the measurement of the CEA and AI soon after reduction and removal of the Batchelor POP. Other areas of importance will be discussed in passing where deemed relevant, or presented in the appendices.

1.3 Diagnosis

Diagnosis and severity assessment are paramount to a good outcome. This can be assessed clinically and supplemented using ultrasound, X-rays, computed tomography (CT) or magnetic resonance imaging (MRI).

The diagnosis of DDH in the neonate should be clinical. Careful history taking must include checking for a family history of DDH and a detailed perinatal history (association with primigravidae, breech position and oligohydramnios).

It is important to differentiate a purely dysplastic hip with a reduced femoral head from a subluxed or dislocated femoral head, as the management for these is completely different. The patients recorded in this

series all had a dislocated hip that required a formal reduction (closed or open). About half then required a secondary procedure before final follow-up to ensure good femoral cover to delay the onset of osteoarthritis.

Asymmetric skin folds in the buttock or gluteal region and limb length discrepancy are suggestive of DDH. Any other lower limb deformity, torticollis, metatarsus adductus or any other significant musculoskeletal abnormality must be investigated. Reduced abduction is a classic sign. The dislocating and relocating tests of Barlow and Ortolani are significant in the neonate.

Ultrasonography can be used to confirm clinical suspicion in the neonatal period. It has gained popularity as a screening tool in most first world countries. It was introduced by Graf in 1983 and its effectiveness has been proven by many authors in screening for DDH after the neonatal period.⁴ Ultrasound is also useful to confirm reduction once a Pavlik harness has been applied.

Radiographs are used to diagnose infants with DDH and to serially monitor response to treatment, potential complications and resultant remodelling. Radiographs were the main method of assessment in this study.

Arthrography has been used to assess the cartilaginous component of the femoral head post-reduction in younger patients.⁵ By measuring the medialization ratio (percentage of the horizontal radius of the cartilaginous femoral head that lay medial to Perkin's line) intra-operatively, at the time of reduction, Forlin et al⁶ found that the medialization ratio measured 75% in hips with a good result, 66% in hips with a fair result and 57% in hips with a poor result.

Computed Tomography (CT) is being used more frequently today to better appreciate the 3-D spatial orientation of the acetabulum. Excessive femoral anteversion can be assessed with CT. Anteversion is not a universal finding with DDH; therefore knowledge of it being present may help the surgeon in pre-operatively planning any form of acetabuloplasty. Its use is probably of greater value in the older child when more of the acetabulum has ossified. Concerns regarding radiation exposure, cost and availability have been raised.⁷ It was not routinely performed during the time of this study.

Magnetic resonance imaging (MRI) is also being used more frequently to better delineate subtle intra-articular abnormalities and volume discrepancies between the femoral head and acetabulum to help guide treatment. It is also useful to assess the early outcome of operative procedures, especially when large areas of cartilaginous tissue are being assessed.⁸ Again, it was not routinely performed during the time of this study.

1.4 Clinical Evaluation

The final clinical outcome will be assessed using the McKay clinical assessment.

Specific outcome parameters (degenerative arthritis and joint arthroplasty) were not used, as follow-up for these outcomes was insufficient and degenerative arthritis had not yet developed.

1.5 Radiological Evaluation

Radiographs will be the main method of investigation in this study. In particular the CEA and AI will be measured to assess subluxation, the severity of the dysplasia and subsequent acetabular remodelling.

The CEA (centre edge angle) is an index of the utilization of the acetabulum by the femoral head. It is measured by drawing a line parallel to Perkin's line through the centre of the head of the femur and bisecting this line with another line through the most lateral margin of the acetabulum.

The AI (Acetabular Index) is an index of formation and remodelling of the acetabulum with regard to coverage of the femoral head. The angle is formed by Hilgenreiner's line and a line bisecting this line, through the upper part of the triradiate cartilage and then through the most lateral margin of the acetabulum.

The seminal work of Wiberg in 1939⁹ and Tonnis in 1976¹⁸ helped to lay the groundwork for investigating acetabular dysplasia. Tonnis developed a table using AI as a measure of dysplasia at different ages in boys and girls for comparison. Any hip with an AI above one standard deviation of the mean had questionable dysplasia and a value over two standard deviations had definite dysplasia. The AI on its own could be reliably used up to the age of 10 years. This was used as a diagnostic tool.

We used the most lateral bony margin of the acetabulum to measure the AI and CEA (classical method) as shown in Figures 1.5.1 – 1.5.3. This represents the anterolateral portion of the acetabulum. The lateral end of the sourcil was not used to measure the AI or CEA – this point represents the mid-superior portion of the lateral edge of the acetabulum. Several authors have shown that the lateral bony margin gives a more reliable and reproducible measurement.¹⁰

Ogata et al¹¹ and Omeroglu et al¹² have used the lateral margin of the sourcil as the ‘refined CEA’ – this point was used so as not to overestimate the CEA. These angles have been confirmed to be slightly more accurate for the lateral margin of the acetabulum using CT scan comparison. The ‘refined CEA’ is still not generally used and in this thesis the better known ‘classic CEA’ was used.

Omeroglu et al¹³ confirmed that the classical technique to measure CEA had a higher intra- and inter-observer agreement than the refined technique of Ogata. They found a 3° intra- and 4° inter-observer difference using the classic CEA technique. This value is lower than the value of 9° given by Broughton et al.¹⁹

The approximation of the CEA used in this study will be called the ossific nucleus centre edge angle (ONCEA) and will refer specifically to the approximation of the CEA, measured within six months of removing the Batchelor POP, following closed or open reduction. The ONCEA was measured at a mean age of 18 months, whereas the CEA is said to be accurate from only five years of age.⁹

In this study, the centre of the ossific nucleus is used to calculate the ONCEA. As the ossific nucleus continues to ossify and the physis flattens out and widens, the technique of using Mose rings is used to obtain the centre of the femoral head.

Figures 1.5.1–1.5.3 show how the centre of the ossific nucleus is used in these young patients (mean age 18 months) to determine the ossific nucleus centre edge angle (ONCEA). The volumetric centre of the femoral head is used with the Mose technique as the child gets older to measure the CEA. The Mose technique is also used as the ossific nucleus ‘flattens out’ and the physis widens and becomes more horizontal.

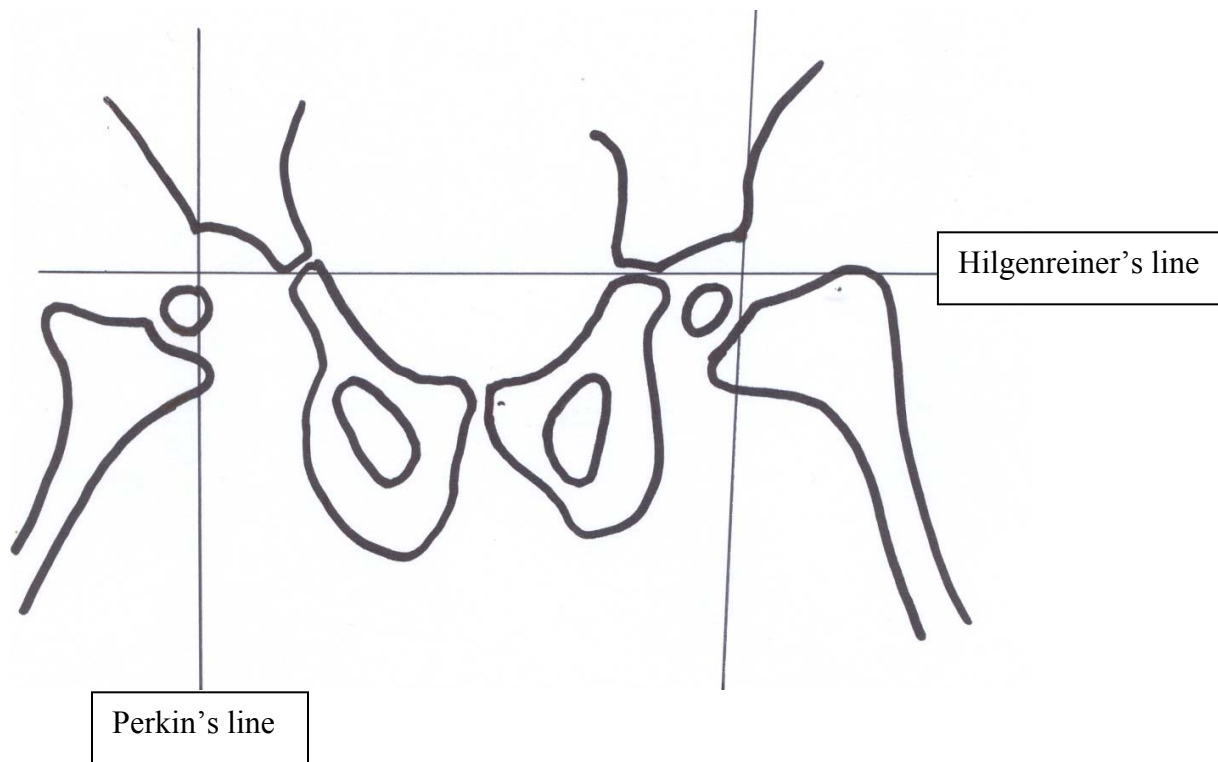


Figure 1.5.1 Pelvic X-ray at 20 months of age. Hilgenreiner's and Perkin's lines – the right hip is subluxed

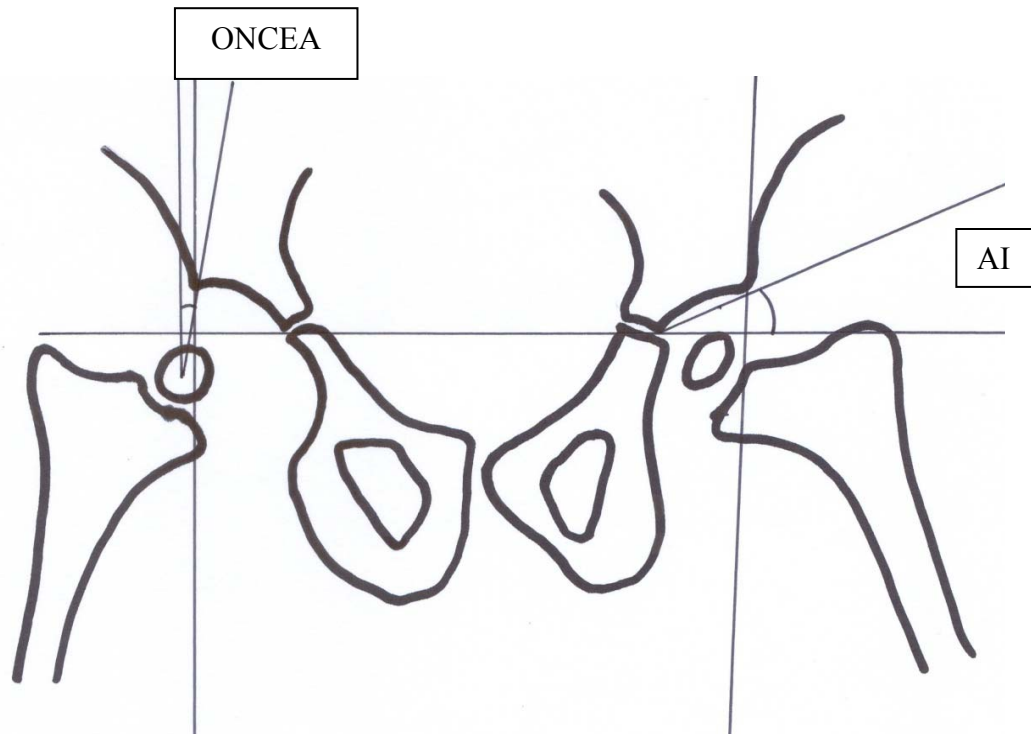


Figure 1.5.2 Pelvic X-ray at 20 months of age. Ossific nucleus centre edge angle (ONCEA) on the right measures -10° (severe subluxation). The centre of the ossific nucleus and the outermost lateral edge of the acetabulum are the two reference points to calculate the angle. On the left the acetabular index (AI) is normal and measures 24° .

The acetabular index is measured on Hilgenreiner's line from the triradiate cartilage to the outermost edge of the acetabulum.

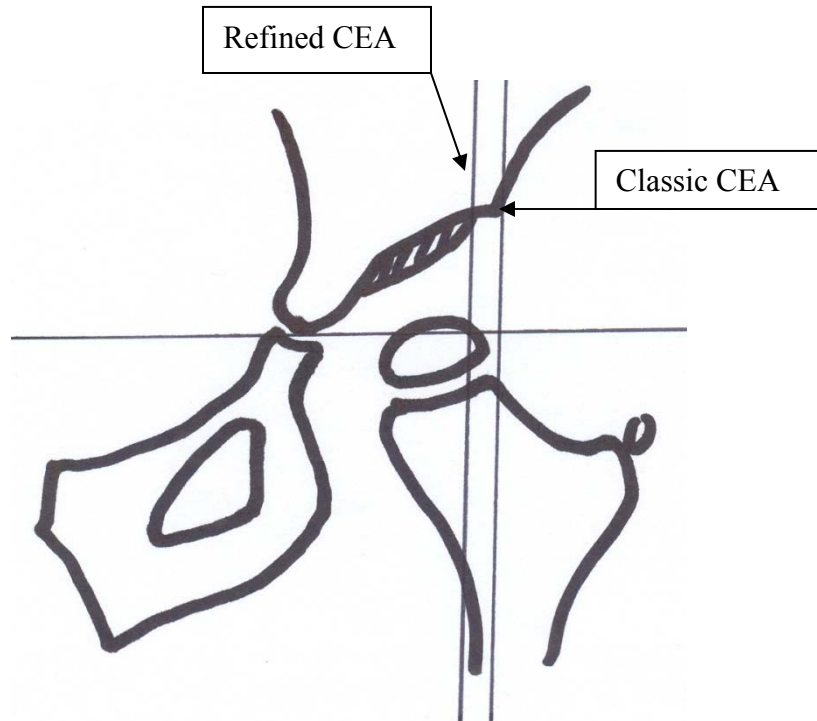


Figure 1.5.3 Classic CEA compared with the Refined CEA (Ogata). In this study the lateral border of the acetabulum is used (Classic CEA). The Refined CEA is measured by using a point at the lateral margin of the source as depicted above.

Further examples are illustrated in figures 1.5.4.1 to 1.5.4.4, showing the technique used to determine the ONCEA and ONCEA/AI.

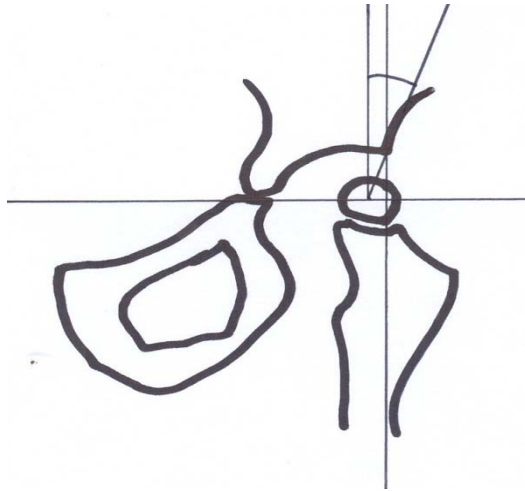


Figure 1.5.4.1 16 months – ONCEA 16° and ONCEA/AI 0.67 (Reduced)

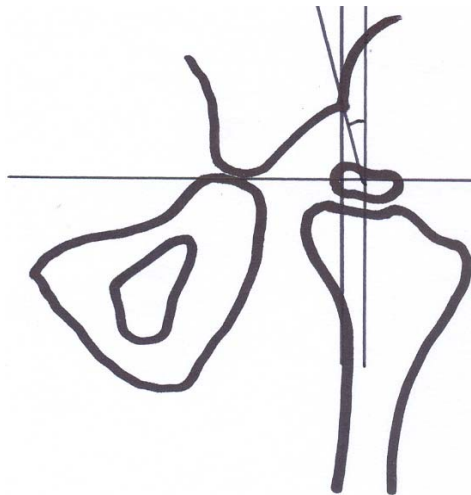


Figure 1.5.4.2 21.5 Months – ONCEA -14° and ONCEA/AI -0.41 (Severe subluxation)

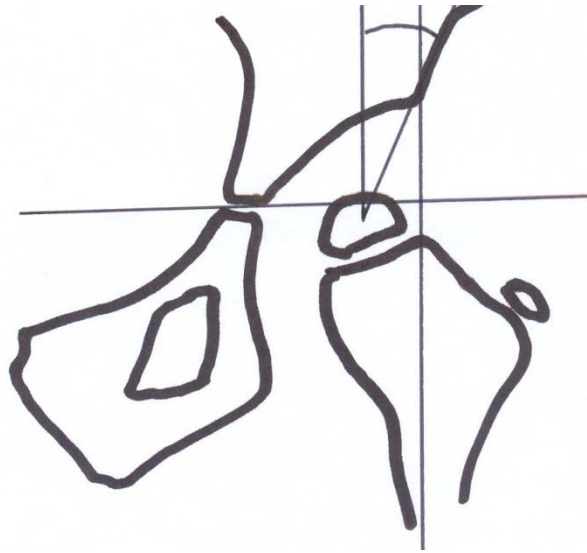


Figure 1.5.4.3 34 Months ONCEA 22° and ONCEA/AI 1.45 (Reduced)

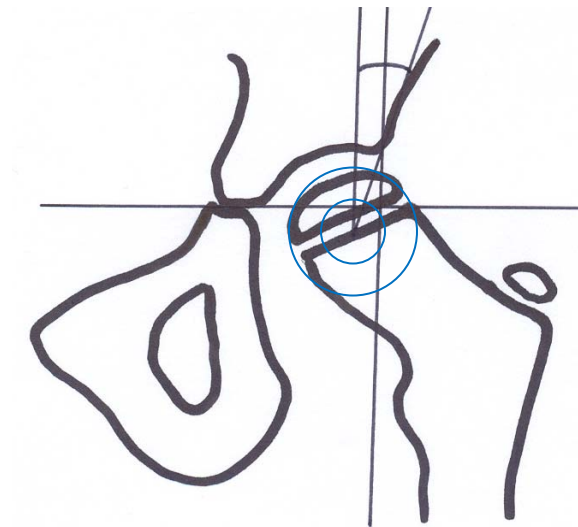


Figure 1.5.4.4 29 Months ONCEA 20° and ONCEA/AI 1.2 (Reduced). When the physis and femoral head ‘flatten’, the volumetric centre of the femoral head is used to measure the CEA, using the Mose ring technique.

The reliability of using the CEA and AI has been validated in various studies.^{14 15 16} Concerns regarding these measurements are that they are age-specific: the CEA is said to be accurate only from the age of five years and the AI is said to be useful up to the age of eight years. The literature is sparse regarding the use of these measurements at an earlier age. In this clinical audit we will use these measurements alone and together as a ratio to see if they can be used at an earlier age – after reduction, in the first six months following the removal of POP. This has not been used or recorded in the literature as far as we are aware. This angle will be specifically referred to as the ossific nucleus centre edge angle (ONCEA).

Radiographic assessment in the older child is easier. Sharp¹⁷ looked at using the acetabular angle in patients who had already fused the triradiate cartilage – this angle was called the acetabular angle of Sharp and referenced off the ‘inferior part of the tear drop’ as opposed to the triradiate cartilage for Hilgenreiner’s line. An angle below 42° was considered normal. The CEA can be measured after closure of the triradiate cartilage. Sharp found the CEA of Wiberg used during the first three years of life had large variation because of the difficulty in finding the centre of the femoral head. The lowest normal limit for the CEA between 5-8 years was 19°, 9-12 years was 25°, and 13-20 years was 26°-30°. This value was used as a diagnostic tool.

In the current study the average age at which the ONCEA was measured was 24.1 months. By this time the ossific nucleus was visible in all patients, thus enabling measurement of the ONCEA.

Tonnis¹⁸ proposed a hip value by using a combination of the CEA, ACM angle of Idelberger and Frank and the distance MZ between the centre of the femoral head and the centre of the acetabulum to prognosticate acetabular development (as shown in Figure 1.5.5). The value of this system could only be used in adults (21-50 years) and is not used for the present study, but is included for completeness.

Tonnis found that the CEA could only be used reliably after three years of age because of large differences in measurements arising from difficulties in finding the centre of the head. In younger patients the epiphysis moves laterally with external rotation.

In the present study, all the patients had radiographs taken in the same radiology suite where the method of positioning was standard for all patients – by doing this the reliability and reproducibility was maximized.

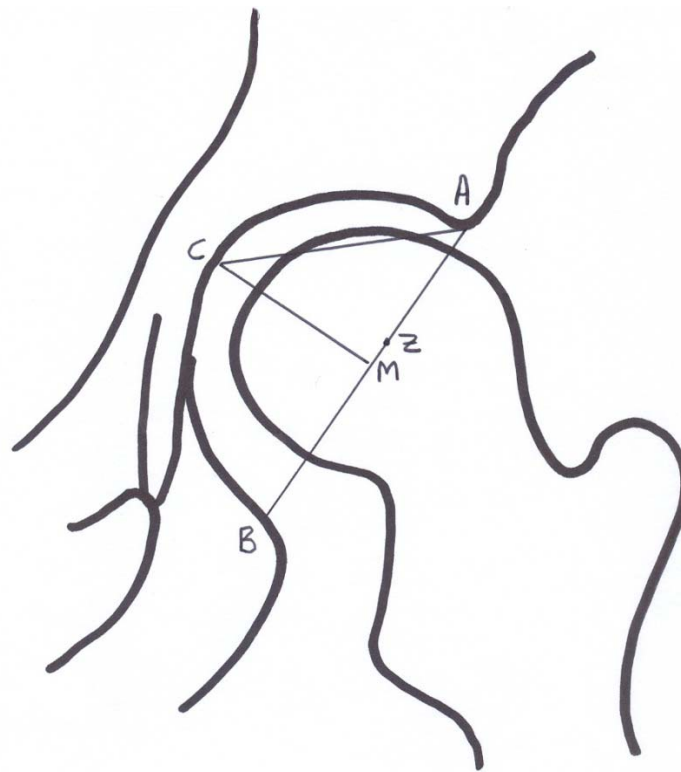


Figure 1.5.5 ACM angle of Idelberger and Frank. Z is the centre of the femoral head

The ONCEA was used before the age of five years and combined with the AI in the form of a reproducible and reliable ratio.

The ONCEA was measured by using the volumetric centre of the ossific nucleus in young patients (less than three years) and the best fit of 'Mose' rings as the femoral epiphysis develops to gradually obtain the traditional method of measuring the CEA.

Broughton et al¹⁹ concluded that the AI should be given a range of 6° and CEA a range of 9° to be 95% confident of a true measurement. AI was most helpful up to the age of eight years and CEA over the age of five years. Progression of a value (AI or CEA) was found to be of more value than a single measurement.

In this study, progression of the CEA after removal of the POP was followed for six months to find the lowest CEA and then the CEA at final follow-up was used to determine the Severin score. The three groups also help to minimize the error in measuring the ONCEA, with the middle group having a range of 18°.

The reliability of these measurements was also established by Carney et al.¹⁵ For the AI, the intra observer reliability was 4° and the inter observer reliability was 8°. These results closely follow those of Broughton et al.¹⁹

The complication of AVN will be described according to the Kalamchi and MacEwan classification in the next chapter. With AVN group III and IV, the reliability of the CEA has been questioned by Taketa et al²⁰ who found a high correlation between the CEA and AI in patients who had either no AVN or AVN group I or II only.

The use of AI was found to be reliable both for intra- and inter-observer comparisons but the CEA was found to be reliable only for intra-observer comparisons by Tan et al.²¹ In the present study, the candidate measured all the angles himself in every patient's radiographs. This increased the reliability of consecutive CEA readings. A sample was checked by each supervisor.

In unilateral cases the opposite hip was not used as a control to measure CEA and AI. Jacobsen et al²² have shown that the contralateral 'normal' hip is often dysplastic when it is carefully examined using CT. This may therefore invalidate any data collected for comparative purposes.

The above factors have been taken into account and the inferred reliability will be deemed acceptable. The method of CEA measurement has been discussed: we will use the volumetric centre of the ossific nucleus in young patients (less than three years) and the best fit of 'Mose' rings as the femoral epiphysis develops to gradually obtain the traditional method of measuring the CEA. We used the most lateral bony margin of the acetabulum to measure the AI and CEA.

Authors have disagreed as to the age at which acetabular remodelling ceases. This has implications for management. As the potential for remodelling decreases, the success of management will also decrease. The earlier a child is treated, the better the remodelling potential of the acetabulum.

Schwartz²³ found that the growth potential of the acetabulum was up to two years following reduction. Harris et al²⁴ found it to be four to five years following reduction. Lindstrom et al²⁵ found it to be up to eight years of age if the initial reduction was concentric. Gotoh et al⁵⁷ found that acetabular remodelling occurred up to the age of 10 years.

The senior supervisor, AS, used six years of age as the age at which development of the acetabulum is essentially complete and this was therefore the minimum age at final follow-up in this study.

All radiographs were assessed by the candidate with confirmation and discussion in a sample of the population by both the supervisors in order to improve the reliability of the measurements.

1.6 Management

The treatment protocol was dependent on the age at presentation.

The protocol followed in all patients was as follows:

1. In pre-walking age a closed reduction was performed, and a Pavlik harness fitted. Those successfully treated by Pavlik harness were excluded from this study.
2. In older children where a simple reduction and fitting of a harness was not possible, pre-operative traction was used. The children were placed in Gallows traction; and slow steady abduction to 45° was then done. This was done for a variable period of time, depending on the laxity of the patient. A gentle closed reduction was performed under general anaesthetic.
3. If a closed reduction failed, an open reduction was proceeded to.
4. Post-operatively the patients were immobilized in a POP spica for three months. The spica was changed at six weeks. On removal of the spica at three months, the patients were then kept in a Batchelor POP for a period of between six and 12 weeks. The application of a POP spica is demonstrated in Figure 1.6.1.
5. Secondary procedures were then performed at five years of age if the AI was abnormal.

The length of time for pre-reduction traction varied. As there was therefore no standardization, it could not be assessed for its possible association with the outcome of these patients.

All closed reductions were gentle, and no forced reduction was ever attempted. The hip spicas were applied in 90° of flexion, and in the safe zone of abduction, halfway between maximal abduction and the point of dislocation (Ramsey's safe zone). Adductor tenotomy was performed when indicated.

An open reduction was performed via an anterior approach to the hip. A modified Salter incision was used, the iliac apophysis split, and the hip joint approached sub-periosteally. The reflected head of the rectus as well as the straight head were detached from the pelvis and reflected distally. The hip joint capsule was opened through a T-shaped incision, the ligamentum teres was excised, and the fat pad when present was excised as well. A psoas release was performed. Following reduction of the femoral head into the acetabulum, a capsulorrhaphy was performed by advancing the superior part of the capsule inferiorly and medially. The iliac apophyses were then sutured back anatomically. A portovac drain was inserted. Skin was sutured with a subcuticular absorbable suture.

The importance of soft tissue interposition after reduction and subsequent acetabular development has been reviewed by means of an arthrogram at the time of closed reduction²⁶. Some groups oppose²⁷ and others support²⁸ the need for open reduction following soft tissue interposition on the arthrogram. The majority of patients in this review had no arthrogram done at the time of closed reduction, as the surgeon (AS) believed that it would not influence the outcome. A conservative approach following initial reduction and a subsequent secondary procedure if needed at five years of age was followed in the majority of patients.

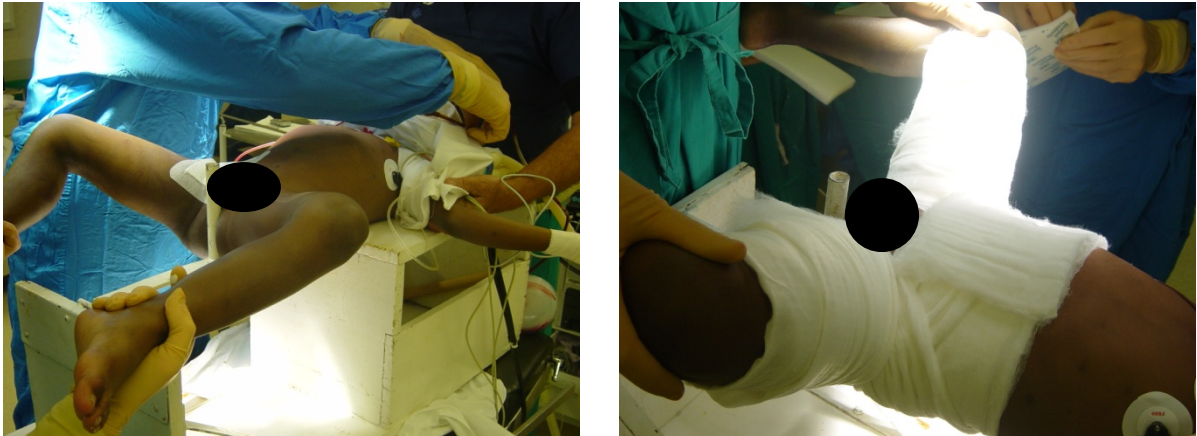


Figure 1.6.1 Application of POP Spica. The patient is positioned onto the spica table to facilitate cast application. Orthopaedic wool and ‘rest-on-foam’ are used to ensure comfortable padding before the application of the POP.

The prognosis and need for a secondary procedure should ideally be predicted for around the time the Batchelor POP is removed so that the parents can be adequately informed regarding the future management of the child. If this can be done early, the need for repeated reduction and associated risk of avascular necrosis can also be reduced by doing a secondary procedure directly.^{29 30}

Salter³¹ treated all hips that presented on or after 18 months of age with an open reduction and simultaneous Salter innominate osteotomy. He has subsequently published an 86% survival rate at 40-year follow-up, and a 54% survival rate at 45-year follow-up.³² The Salter osteotomy is shown in Figures 1.6.2.1–10.

The Salter innominate osteotomy has been shown to be an effective procedure either in combination with an open reduction and femoral shortening³³ or on its own as a later secondary procedure. Barrett et al³⁴ showed that almost 75% of patients with Salter osteotomy had excellent or good radiographic and clinical results. The

osteotomy reliably improved the overall coverage of the femoral head, increasing the AI on average by 16°. The age at surgery for their 68 hips ranged from 18 months to 11.5 years (average 6.7 years) and the patients were followed up between 5.5 and 10 years post-operatively.

In the current series of patients the commonest secondary procedure performed was the Salter osteotomy. Other secondary procedures included Chiari osteotomy, Pemberton osteotomy, triple osteotomy, and a variety of femoral osteotomies.



Figure 1.6.2.1 Salter Osteotomy. A transverse modified Salter skin incision is made, at the midpoint of the anterior superior and inferior iliac spines, with equidistant medial and lateral limbs. The skin is undermined by blunt dissection to allow free mobility.



Figure 1.6.2.2 Salter Osteotomy. The iliac crest is split in its length.

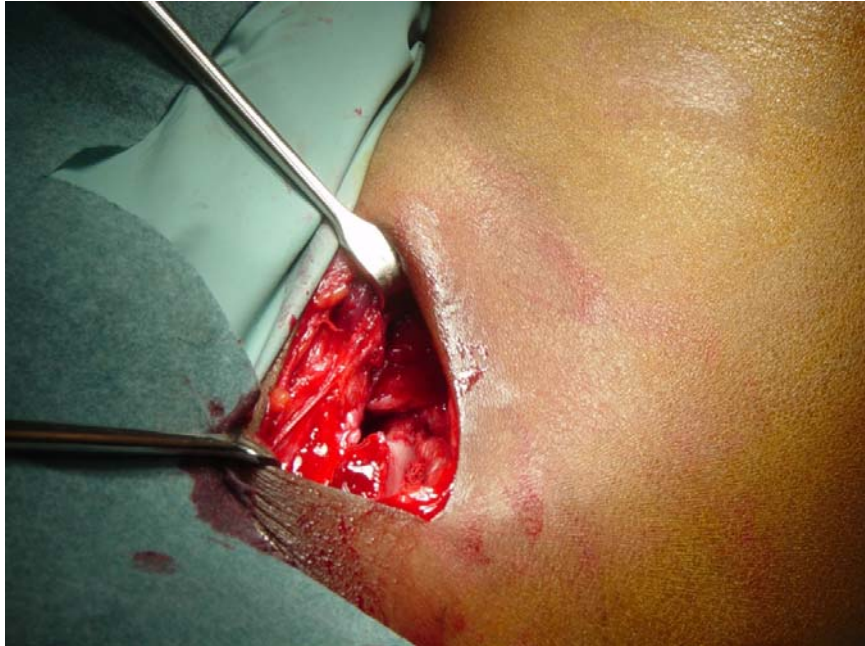


Figure 1.6.2.3 Salter Osteotomy. The iliac blade is exposed sub-periosteally.

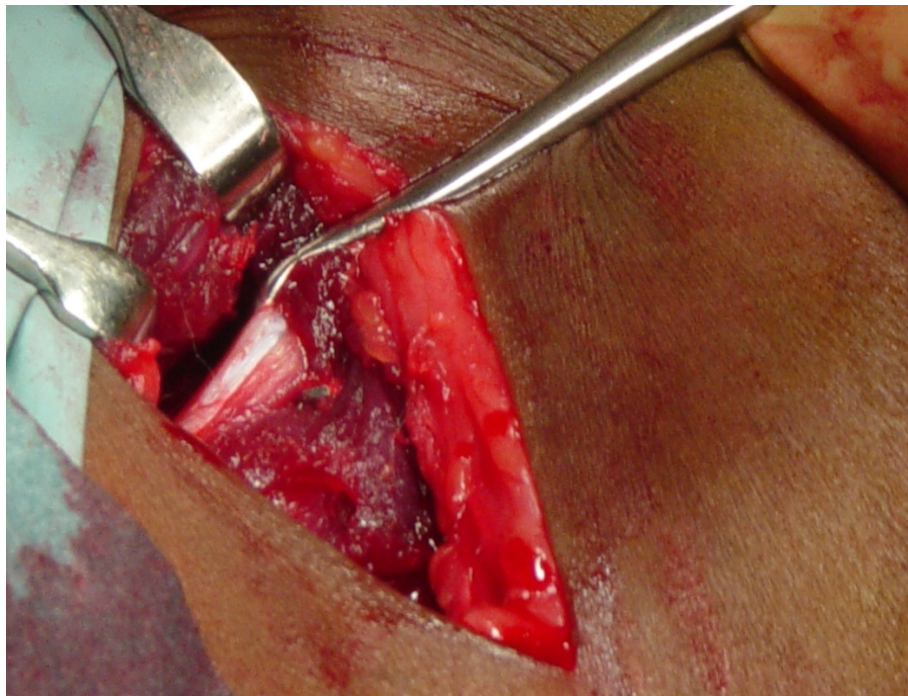


Figure 1.6.2.4 Salter Osteotomy. An iliopsoas tenotomy is performed.



Figure 1.6.2.5 Salter Osteotomy. A Gigli saw is placed through the greater sciatic notch and the innominate osteotomy is performed.



Figure 1.6.2.6 Salter Osteotomy. A wedge of bone is resected from the antero-superior portion of the iliac blade.

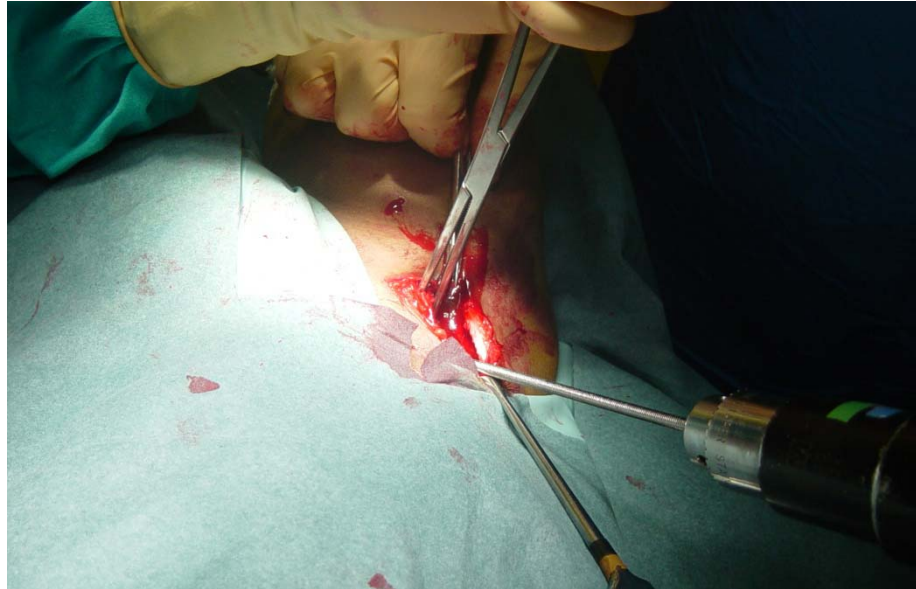


Figure 1.6.2.7 Salter Osteotomy. The distal half of the pelvis is maximally displaced anteriorly and laterally, and kept in this position by inserting the bony wedge into the osteotomy. The osteotomy and wedge are then secured using two threaded Steinman pins.

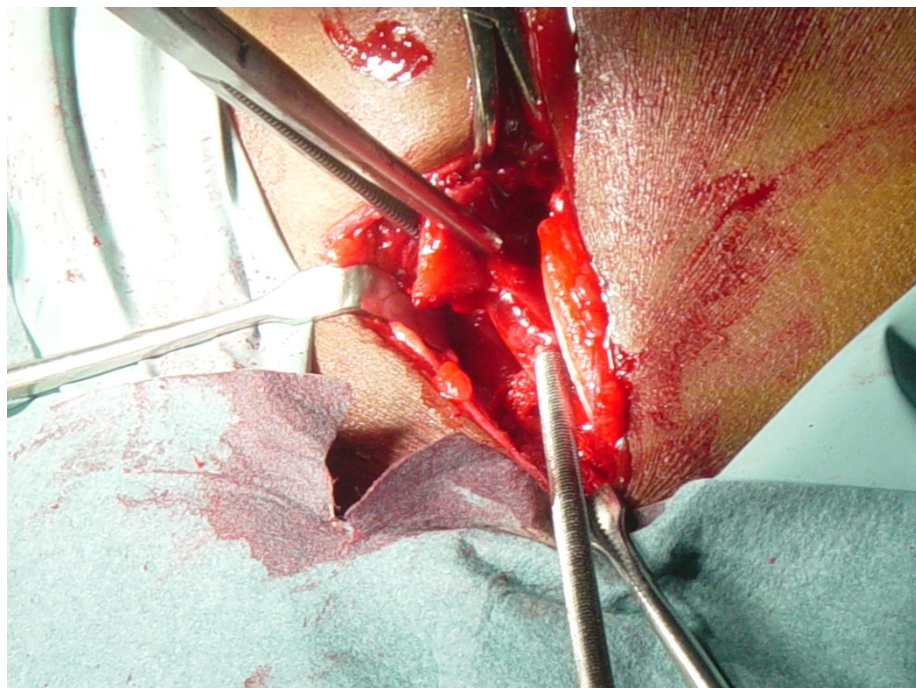


Figure 1.6.2.8 Salter Osteotomy. Securing the bone wedge and osteotomy. Check that the Steinman pins do not protrude into the hip joint.

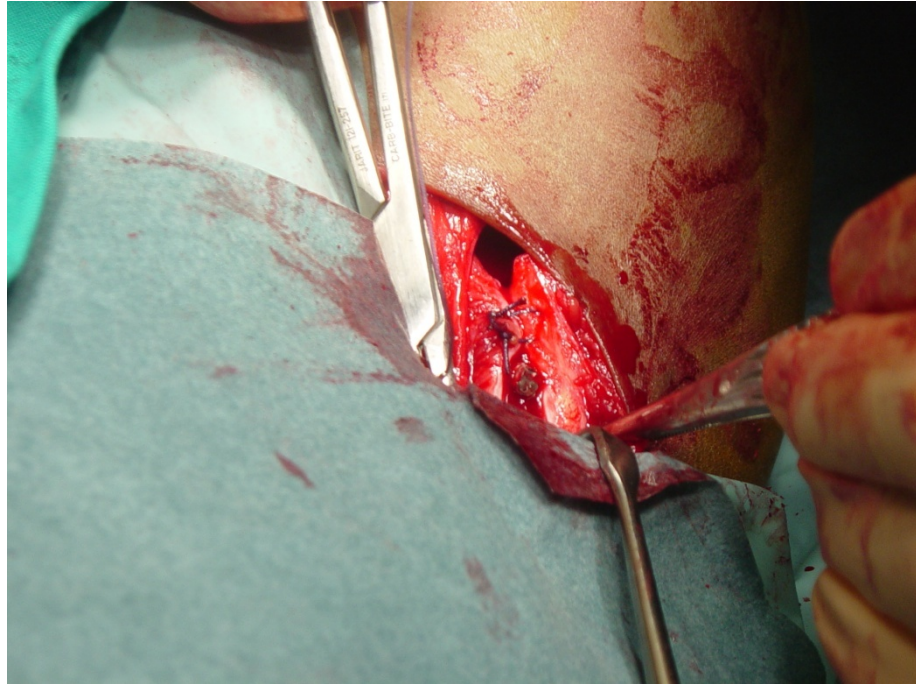


Figure 1.6.2.9 Salter Osteotomy. The iliac apophysis is replaced and sutured with an absorbable suture.



Figure 1.6.2.10 Salter Osteotomy. An 1/8 inch 'portovac' drainage tube is inserted before final closure with monocryl subcuticular sutures.

2.0 MATERIALS AND METHODS

2.1 Objectives

The outcome of DDH has been well described in the literature.^{35 36 37 38 39} The objective was to determine the prognostic importance of early subluxation regarding further management (especially the need for secondary procedures) and final outcome. Early subluxation was measured using ONCEA and ONCEA/AI within six months of removing the POP, after formal reduction.

2.2 Hypothesis

Null hypothesis: If the hip subluxes after reduction and is observed, many of these patients will require a secondary procedure at five years to obtain a good result but will not necessarily require further attempts to reduce the hip.

2.3 Aims

The aim is to prove the null hypothesis: does the diminishing ONCEA (subluxation) require prompt treatment (repeat reduction or early secondary procedure) or can it be observed with the knowledge that it will improve on its own or require a secondary procedure if necessary at the age of 5 years?

2.4 Methods

The population was drawn from 220 patients with DDH. Only patients with DDH requiring a formal closed or open reduction under general anaesthetic, application of spica cast and follow-up till at least six years of age were included.

Exclusion criteria were as follows: less than six years of age at final follow-up, teratological DDH (arthrogryposis), acquired dislocation (cerebral palsy, trauma, sepsis), inadequate X-rays or clinical notes and

patients who were successfully treated with a Pavlik harness and did not require a formal closed or open reduction.

Patient files including all clinical and surgical records were reviewed to obtain all AIs and CEAs on every X-ray taken on every patient throughout the treatment period and subsequent follow-up.

The study design is in the format of a retrospective clinical audit.

2.5 Clinical evaluation

The modified McKay score was determined from the available clinical notes at final follow-up.

McKay published his scoring system⁴⁰ to compare the early results of DDH patients treated with a Salter or Pericapsular osteotomy. The original McKay score is shown in Table 2.5.1.

Table 2.5.1 Original McKay Classification Score

Group	Description
I (Excellent)	Stable, painless, no limp, negative Trendelenburg sign and full range of motion
II (Good)	Stable, painless, normal gait or slight limp, negative Trendelenburg sign and slight limitation of motion
III (Fair)	Stable, painless limp and/or positive Trendelenburg sign and/or moderate limitation of motion
IV (Poor)	Unstable, painless, limp and/or positive Trendelenburg sign and severe limitation of motion, but not dislocated
V (Failure)	Unstable, painful or painless, limp and positive Trendelenburg sign and dislocated

In the current study the modification as described by Berkeley et al⁴¹ was used and is shown in Table 2.5.2. This also helped in ensuring enough hips in each group for statistical purposes.

Table 2.5.2 Modified McKay Classification

Group	Description
I (Excellent)	Painless, stable hip, no limp, $\geq 15^\circ$ of internal rotation, negative Trendelenburg sign
II (Good)	Painless, stable hip, slight limp; slight decrease in hip motion, negative Trendelenburg sign
III (Fair)	Minimum pain, moderate stiffness, positive Trendelenburg sign
IV (Poor)	Significant pain, stiff, positive Trendelenburg sign

2.6 Radiological evaluation

The lowest CEA within six months of removal of the Batchelor POP (ONCEA) was measured and divided into the following groups for comparison in the ‘SAS’ statistics programme:

1. ONCEA $\geq 10^\circ$ (Group A - Reduced)
2. ONCEA -9° to 9° (Group B - Mild subluxation)
3. ONCEA $\leq -10^\circ$ (Group C - Severe subluxation)

The age at the time of measuring the ONCEA was recorded.

The associated AI at time of ONCEA was recorded to determine the ONCEA/AI ratio.

A ratio of ONCEA/AI was recorded and divided into the following three groups for analysis:

1. ONCEA/AI > 0.5 (Group A - Reduced)
2. ONCEA/AI 0 to 0.5 (Group B - Mild subluxation)
3. ONCEA/AI < 0 (Group C - Severe subluxation)

The Kalamchi and MacEwan classification was used to assess avascular necrosis (AVN) of the femoral head.

The original Kalamchi and MacEwan classification⁴² has five groups, as shown in Table 2.6.1.

Table 2.6.1 Original Kalamchi and MacEwan Classification of AVN

Group	Description
I	Minimal changes affecting ossific nucleus vascularity (delayed appearance, mottling). Final appearance essentially normal
II	Lateral physeal damage resulting in coxa valga (lateral ossification, lateral physeal irregularity, bridging, lateral notching of epiphysis, lateral metaphyseal defect)
III	Central physeal damage (symmetrical retardation, coxa breva, functional coxa vara)
IV	Total damage to head and physis (delayed ossification, femoral head irregularity, flattening, coxa magna, femoral neck irregularity – varus, short, wide)
V	Unclassifiable due to multiple surgery or severe deformity

In this study the groups were simplified.

Hips without AVN = group 0.

Non-significant AVN = AVN group A (original group I).

Significant AVN = AVN group B (original groups II, III, IV and V).

This modification of the original Kalamchi and MacEwan Classification was presented at the annual South African Orthopaedic Association (SAOA) annual conference, September 2006, Durban, South Africa, and was used in an effort to simplify the classification. It also helped to predict outcome – hips with group B AVN had a poorer outcome than hips with either no AVN or group A AVN.

Examples of each type of AVN are demonstrated in Figures 2.6.1 – 2.6.4.



Figure 2.6.1 Kalamchi & MacEwan Group I AVN (Group A)

13 Months – Left ossific nucleus mottled
appearance

7 Years – Essentially normal



Figure 2.6.2 Kalamchi & MacEwan Group II AVN (Group B)

40 Months

22 Years – Coxa valga, with subluxation



Figure 2.6.3 Kalamchi & MacEwan Group III AVN (Group B)

28 Months

14 Years – Coxa breva



Figure 2.6.4 Kalamchi & MacEwan Group IV AVN (Group B)

16.5 Years – Right femoral head destroyed

Acetabular development was assessed using Severin's radiographic classification at final follow-up. The ONCEA and ONCEA/AI was compared with the final Severin score using Fisher's exact test.

The Severin grading system was used in this study. It has been used in many other studies and still seems to be the most widely used classification system to assess acetabular development at final follow-up.^{16 37 43} The original Severin classification system has six classes (Table 2.6.2).

Table 2.6.2 Original Severin Classification for final radiographic outcome of acetabular development

Severin Class	Description	Centre edge angle
I	Normal appearance	$\geq 15^\circ$ (5–13 years) $\geq 20^\circ$ (>14 years)
II	Mild deformity of the femoral head and neck or acetabulum or both	$\geq 15^\circ$ (5–13 years) $\geq 20^\circ$ (>14 years)
III	Dysplasia or moderate deformity of the femoral head and neck or acetabulum or both	$< 15^\circ$ (5–13 years) $< 20^\circ$ (>14 years)
IV	Subluxation of the femoral head	
V	Articulation of the femoral head with a false acetabulum	
VI	Redislocation	

In this study classes I-III were used as described above, but classes IV-VI were combined and described as class IV in an attempt to simplify the classification. This was also done for statistical purposes: it would ensure that there would be enough cases in each group for comparison.

2.7 Statistical tests

Descriptive and analytical statistics were used to evaluate results. Prof Fatti, previous head of School of Statistics, University of the Witwatersrand, and DMSA, a statistical company associated with the University of the Witwatersrand, assisted in advising and calculating the relevant statistics. The data was compared using the Chi square test, the one-way ANOVA test or the Fisher exact test (significant if p value <0.05).

The SAS Institute Inc. Cary, NC, USA programme was used to identify significant relationships within each of these data groups.

Excel (Windows XP) was used to identify each patient:

- Gender
- Side DDH involved
- Bilaterality
- Previous management prior to first visit
- Age at presentation
- Age at final follow-up
- Use of Pavlik harness
- Prereduction traction and period applied for
- Closed reduction and age at reduction
- Open reduction and age at reduction
- Secondary procedure and age at surgery
- Date of each radiograph and treatment performed
- CEA both sides at every visit, including ONCEA
- AI both sides at every visit

- ONCEA divided into 3 groups: $\leq -10^\circ$, -9° to 9° and $\geq 10^\circ$
- Associated AI at time of ONCEA
- Ratio ONCEA/AI divided into 3 groups: < 0 , 0 to 0.5 and > 0.5
- Shenton's line intact or broken
- Final Severin class (modified)
- Final Kalamchi and MacEwan grade (modified)
- Final McKay group (modified)

2.8 Pilot study

A large group of these patients were reviewed at the South African Orthopaedic Association Conference in Durban, September 2006, where the complication of AVN was focused on. The study of these patients revealed trends, and this provided the impetus for the continuation of this study. The null hypothesis was decided on from observing several patients who did not require any procedure, despite a negative ONCEA (subluxation).

2.9 Bias/confounding variables

A small number of patients may have been treated elsewhere prior to seeing AS. Where this was the case was mentioned, and such patients were included only if full records on prior management were available.

The patients were treated at a private clinic: this is unlikely to add bias to the series, as the pathology, management and follow-up paralleled that being performed at the Johannesburg provincial hospital at the time.

2.10 Limitations

1. Retrospective study design.
2. The ONCEA has not been used in the literature previously to prognosticate outcome in DDH.
3. Some authors do not believe that the Severin score is reliable. However, it is still used as an outcome measure by many orthopaedic surgeons. Its reliability and reproducibility have been validated as described above and so it will be used in this study to measure radiographic outcome.

3.0 RESULTS

3.1 Demographic Data

Table 3.1.1 shows that 133 hips were studied, the majority being female (94 hips).

Table 3.1.1 Demographics showing number of patients, number of hips and gender

Patients	Hips	Female	Male	Right	Left
101	133	94 (123 Hips)	7 (10 Hips)	54	79

Table 3.1.2 demonstrates the age of the patients at presentation. Most patients (49/101) were between 12.1 and 24 months of age at presentation.

Table 3.1.2 Age at presentation

	0-6 Months	6.1-12 Months	12.1-24 Months	24.1-36 Months	> 36 Months
Number of patients	20	15	49	9	8
Mean Age	18.5 Months				
Range	0-159 Months				

Table 3.1.3 demonstrates the age of the patients at final follow-up. The majority of patients (74 hips) were followed up between the ages of 11 and 15 years.

Table 3.1.3 Age at final follow-up

	6-10 Years	11-15 Years	16-20 Years	>= 21 Years
Number of Patients	42	37	17	5
Mean Age	12.4 Years			
Range	6-26.3 Years			

28 Hips were referred after initial management by another orthopaedic surgeon (21%). A total of 1620 radiographs were reviewed for all 133 hips, giving an average of 12 radiographs for each hip reviewed.

3.2 Clinical Results

At final follow-up the clinical outcome was assessed using the modified McKay score. It was calculated for 126/133 hips (data for seven of the hips was incomplete). In Figure 3.2.1 the final clinical outcome as determined by the McKay group is presented. 77% of the cases were in group I or II at final follow up.

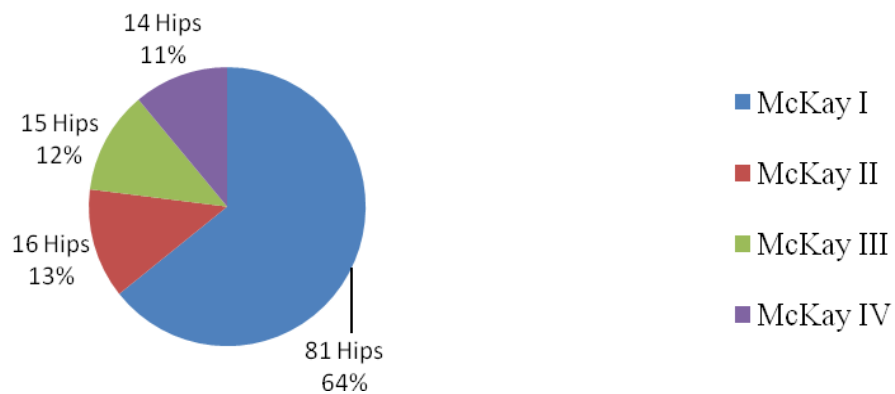


Figure 3.2.1 McKay Groups at Final Follow-Up

Table 3.2.1 shows statistical significance ($p=0.0212$) using Fisher's exact test to compare the three groups of ONCEA with the final McKay score. There were 50/71 (70%) hips with excellent results in ONCEA group A, compared with 7/13 (54%) hips with excellent results in ONCEA group C.

Table 3.2.1 McKay classification compared with all three groups of ONCEA

McKay Group	ONCEA Group A	ONCEA Group B	ONCEA Group C	Total
I (Excellent)	50	24	7	81
II (Good)	6	9	1	16
III (Fair)	4	7	4	15
IV (Poor)	11	2	1	14
Total	71	42	13	126

Table 3.2.2 also shows significance ($p=0.0279$) comparing the ONCEA/AI with the final McKay score. There were 34/44 (77%) hips with excellent results in ONCEA/AI group A compared with 11/20 (55%) hips with excellent results in ONCEA/AI group C.

Table 3.2.2 McKay Classification compared with the three main groups of ONCEA/AI

McKay Group	ONCEA/AI Group A	ONCEA/AI Group B	ONCEA/AI Group C	Total
I (Excellent)	34	36	11	81
II (Good)	2	12	2	16
III (Fair)	2	7	6	15
IV (Poor)	6	7	1	14
Total	44	62	20	126

3.3 Radiological Results

Tables 3.3.1 and 3.3.2 show the age and number in each group of ONCEA. The ONCEA was measured at a mean age of 24.1 months - this is three years earlier than the recommended earliest traditional CEA.

These cases were divided into three groups:

1. Group A (ONCEA $\geq 10^\circ$ or ONCEA/AI > 0.5) (reduced)
2. Group B (ONCEA -9° to 9° or ONCEA/AI 0 to 0.5) (mild subluxation)
3. Group C (ONCEA $\leq -10^\circ$ or ONCEA/AI < 0) (severe subluxation)

Table 3.3.1 Age at which ONCEA measured

	ONCEA
Mean Age ONCEA Measured	24.1 Months
Age Range	8 – 70 Months

Table 3.3.2 Number of hips in each ONCEA group and overall mean ONCEA

	ONCEA Group A	ONCEA Group B	ONCEA Group C
Number of Hips	76	44	13
Mean Overall ONCEA	9°		

Figure 3.3.1 shows the association between mean ONCEA and secondary procedure. The mean ONCEA for patients requiring a secondary procedure was 3° compared with 15° for those not eventually requiring a secondary procedure.

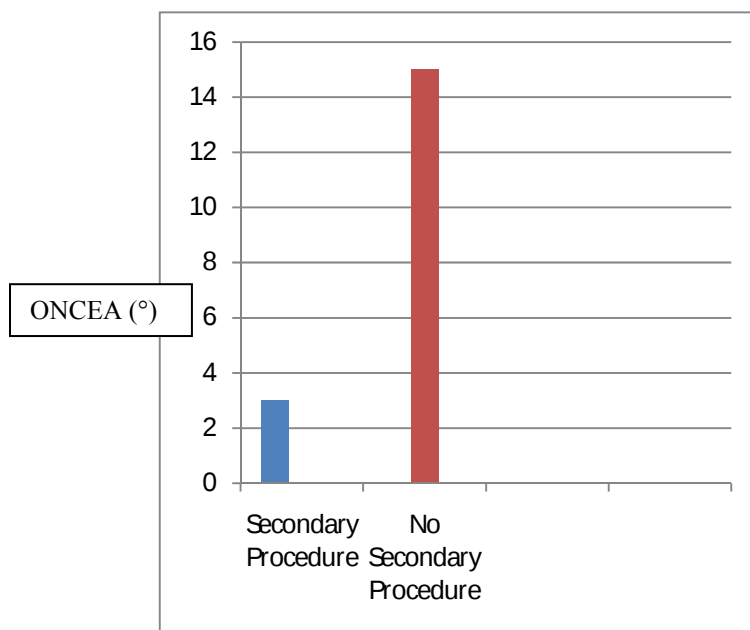


Figure 3.3.1 Mean ONCEA compared with presence or absence of secondary procedures

Table 3.3.3 shows the associated AI at time of ONCEA. Although there was a trend towards a diminishing AI with an increasing ONCEA, the Chi square test showed that there was no statistically significant association between the three groups.

Table 3.3.3 Associated AI at time of ONCEA

	ONCEA Group A	ONCEA Group B	ONCEA Group C
Mean Associated AI	28°	31°	35°

The ONCEA/AI was recorded for the three groups as shown in Table 3.3.4. The majority were in group B with a spread in each of the other two groups.

Table 3.3.4 Number of hips in each group and mean overall ONCEA/AI

	ONCEA/AI Group A	ONCEA/AI Group B	ONCEA/AI Group C
Number of Hips	47	65	21
Overall Mean ONCEA/AI	0.41		

The incidence of AVN was included for completeness sake. The effect of AVN on outcome has been established in a previous study on this population group presented in September 2006 at the annual SAOA conference. Significant AVN was associated with open reduction and a poor outcome. Figure 3.3.2 shows the distribution of AVN in this group of patients. 31% of the cases had significant AVN.

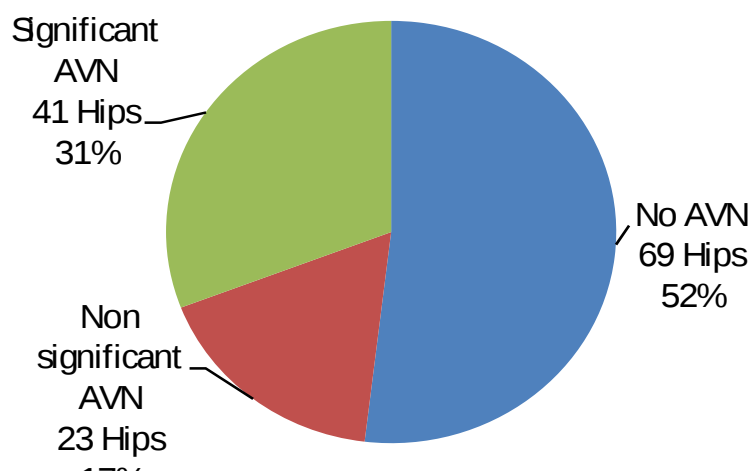


Figure 3.3.2 AVN Groups at Final Follow-Up

The Severin Classification was used to assess the outcome of acetabular development as shown in figure

3.3.3. At final follow-up:

- 60 hips were Severin class I (45%)
- 35 hips were Severin class II (26%)
- 18 hips were Severin class III (14%)
- 20 hips were Severin class IV (15%)

To summarize:

- 95 hips were Severin class I & II (71%)
- 38 hips were Severin class III & IV (29%)

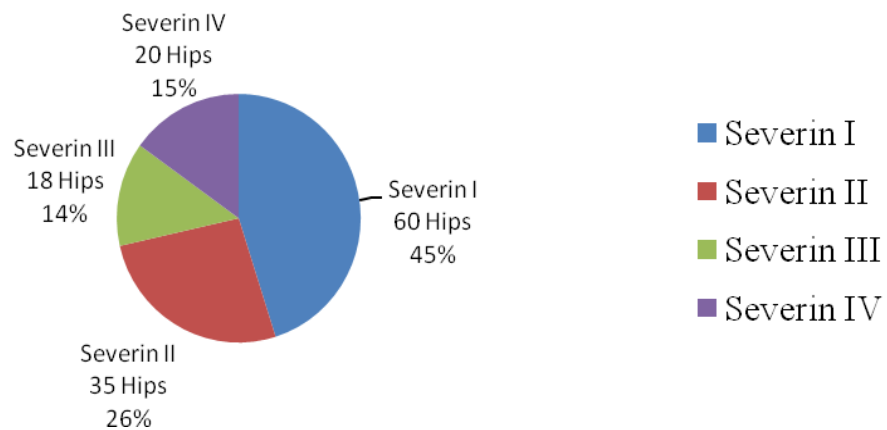


Figure 3.3.3 Severin Classes at Final Follow-Up

The ONCEA had a statistically significant association with the final Severin score. This is shown to be statistically significant in Table 3.3.5 using Fisher's exact test ($p=0.0001$). Figure 3.3.4 is a graphic representation of Table 3.3.5. There were 60/76 (79%) hips in ONCEA group A and 7/13 (54%) hips in ONCEA group C with a Severin class I or II.

Table 3.3.5 Severin Classification compared with all three groups of ONCEA

Severin Class	ONCEA Group A	ONCEA Group B	ONCEA Group C	Total
I (Excellent)	39	20	1	60
II (Good)	21	8	6	35
III (Fair)	13	4	1	18
IV (Poor)	3	12	5	20
Total	76	44	13	133

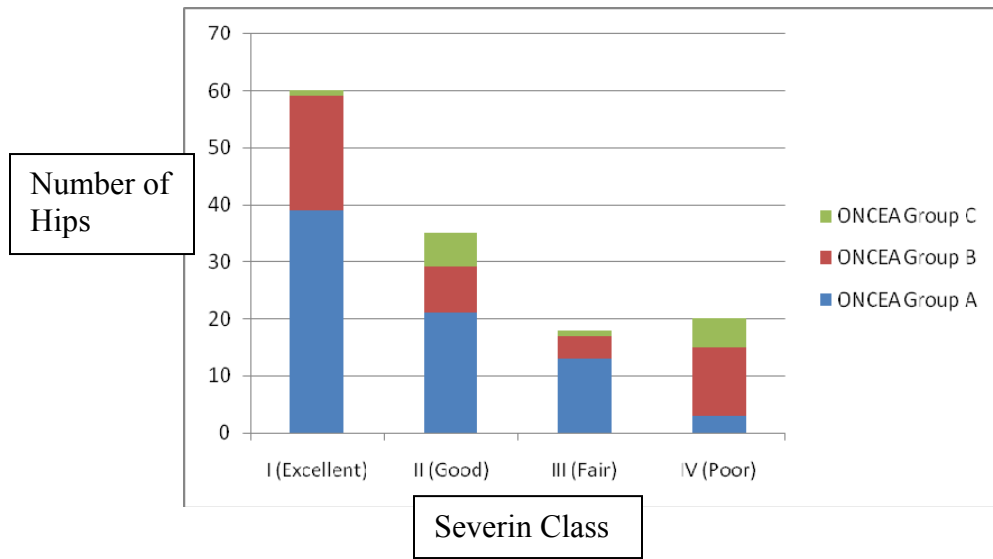


Figure 3.3.4 Severin Classification compared with ONCEA showing number of hips in each group

The association between the ONCEA/AI and final Severin score was also investigated. There was a statistical significance using Fisher's exact test for the three groups ($p=0.0011$), as shown in Table 3.3.6.

Table 3.3.6 Severin Classification compared with three main groups of ONCEA/AI

Severin Group	ONCEA/AI Group A	ONCEA/AI Group B	ONCEA/AI Group C	Total
I (Excellent)	29	28	3	60
II (Good)	10	18	7	35
III (Fair)	6	10	2	18
IV (Poor)	2	9	9	20
Total	47	65	21	133

3.4 Treatment Results

Tables 3.4.1 and 3.4.2 give details regarding the number of reductions performed and time immobilized in POP spica and subsequent Batchelor POP. Closed reductions were performed earlier than open reductions.

Table 3.4.1 Number of closed and open reductions and age at which reduction performed

	Closed Reduction	Open Reduction	All Reductions
Number	76	57	133
Mean Age (Months)	14.6	22.2	18.2
Range (Months)	1.5 – 64.5	6 – 145	12.9

Table 3.4.2 Time spent immobilized with POP spica and followed by Batchelor POP

	POP Spica	Batchelor POP
Mean Time in POP (Weeks)	11.8	9.5
Range (Weeks)	6 – 32	0 – 24

Table 3.4.3 shows that 69/133 (52%) hips had a secondary procedure done at a mean age of 58 months. 58/69 (84%) of the secondary procedures were Salter osteotomies.

Table 3.4.3 Secondary Procedures

	Secondary Procedures	No Secondary Procedures
Number Hips	69	64
Mean Age at Secondary Procedure	58 Months	
Age Range of Secondary Procedures	12 – 152 Months	

A secondary procedure influences the final outcome of each patient. It improves the acetabular coverage of the hip. For this reason the ONCEA was compared with whether a secondary procedure was performed. Using the Chi square test table 3.4.4 shows a statistically significant association between ONCEA and secondary procedures ($p=0.016$). ONCEA was associated with the need for a secondary procedure. In ONCEA group C, 11/13 (85%) hips required a secondary procedure. This is represented graphically in Figure 3.4.1.

It is important to note at this stage that the ONCEA was measured at a mean of 24.1 months of age and that the secondary procedures were performed at a mean of 58 months. Thus a mean of 33.9 months elapsed before a decision was made regarding whether a secondary procedure was indicated (Range 4 – 138 months).

Table 3.4.4 Three main groups of ONCEA compared with need for a secondary procedure

Frequency	ONCEA Group A	ONCEA Group B	ONCEA Group C	Total
No secondary Procedure	44	18	2	64
Secondary Procedure	32	26	11	69
Total	76	44	13	133

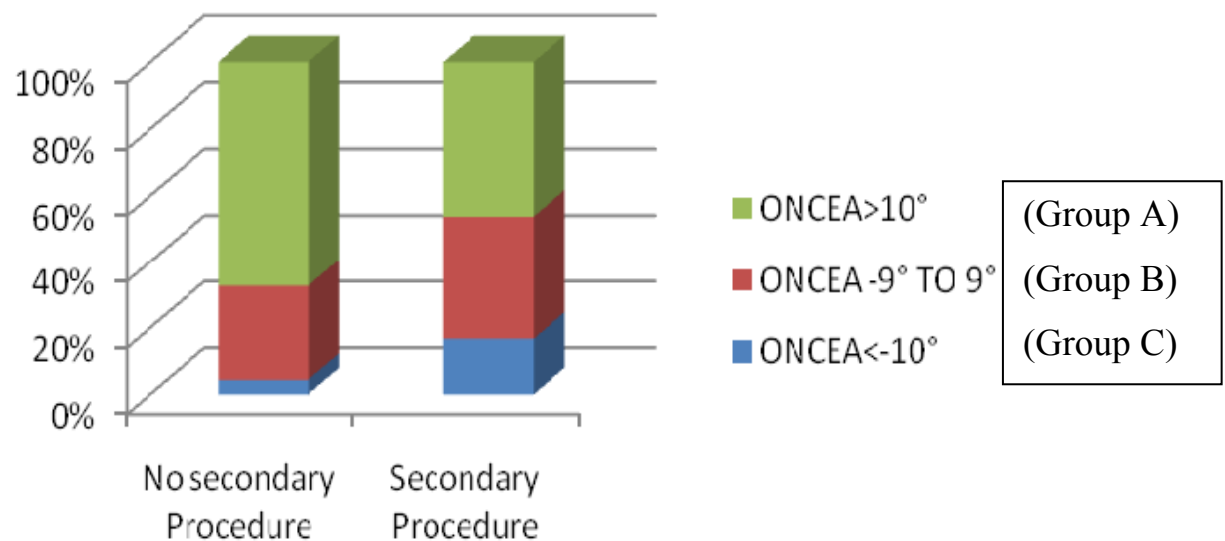


Figure 3.4.1 Three main groups of ONCEA compared with the need for a secondary procedure

In a similar way, table 3.4.5 shows statistical significance with ONCEA/AI for the three groups ($p=0.0002$) with the need for a secondary procedure. In the ONCEA/AI group A 14/49 (29%) hips required a secondary procedure, while in group C, 17/21 (81%) hips required a secondary procedure. This method shows the importance of including the AI, which gives an indication of the degree of acetabular coverage.

Table 3.4.5 Three main groups of ONCEA/AI compared with the need for a secondary procedure

Frequency	ONCEA/AI Group A	ONCEA/AI Group B	ONCEA/AI Group C	Total
No secondary Procedure	35	25	4	59
Secondary Procedure	14	38	17	69
Total	49	63	21	133

Table 3.4.6 shows that 33.9 months passed between the ONCEA being measured and a secondary procedure being performed. This is the time during which acetabulum remodelling will occur.

Table 3.4.6 Time between ONCEA and secondary procedure

	Time between ONCEA and secondary procedure
Mean	33.9 Months
Range	4 – 138 Months

3.5 Case Examples

Case 3.5.1

Unilateral left sided DDH.

Female.

Presented at 16 months.

Followed up to 6.3 years of age.

Successful closed reduction at 16 months.

ONCEA -26° (ONCEA/AI -0.76) at 28 months (group C).

Salter osteotomy done at 29 months.

Excellent outcome – AVN group I, Severin class I, McKay group I.

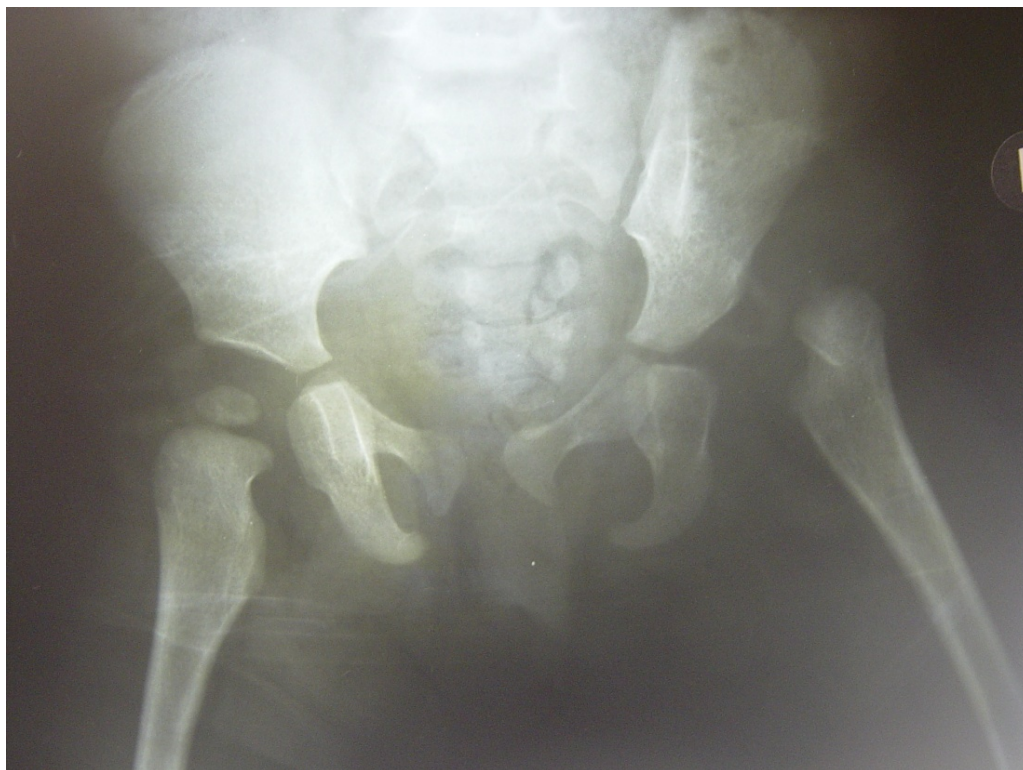


Figure 3.5.1.1 16 Months – age at presentation, left hip dislocated



Figure 3.5.1.2 18 Months of age – post-left closed reduction



Figure 3.5.1.3 21 Months of age, between POP spica and Batchelor POP

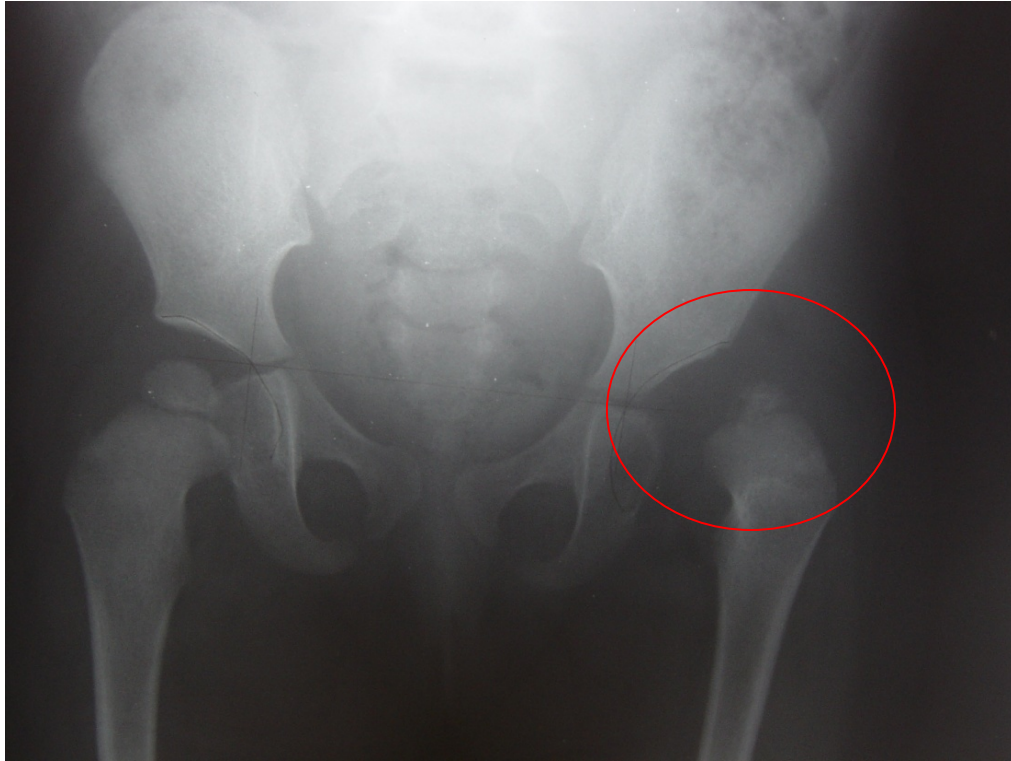


Figure 3.5.1.4 28 Months of age – ONCEA -26° (ONCEA/AI -0.76) (Group C)



Figure 3.5.1.5 32 Months of age – head well reduced, good coverage post Salter osteotomy



Figure 3.5.1.6 4 Years of age – good acetabular remodelling



Figure 3.5.1.7 6.3 Years of age – final follow-up, excellent result

This example is an extraordinary case because although the patient had a group C ONCEA, she had a good result at final follow up. This may be explained by the fact that a successful closed reduction was performed and the secondary procedure was done early – 3 months after the ONCEA was measured, at the age of 2.5 years. The early Salter osteotomy ensured adequate early cover for optimal remodelling, which resulted in an excellent outcome. This case emphasizes that if there is severe subluxation (ONCEA group C), an early secondary procedure can result in a good outcome.

Case 3.5.2

Unilateral left sided DDH.

Female.

Presented for first time at 25 months.

Followed up to 10.7 years.

Successful closed reduction at 25 months.

ONCEA 8° (ONCEA/AI 0.21) at 34 months (group B).

Left Salter osteotomy at 49 months.

Excellent outcome – no AVN, Severin class I, McKay group I.



Figure 3.5.2.1 25 Months of age – first presentation, left hip dislocated



Figure 3.5.2.2 30 Months – post-closed reduction and removal of POP left hip

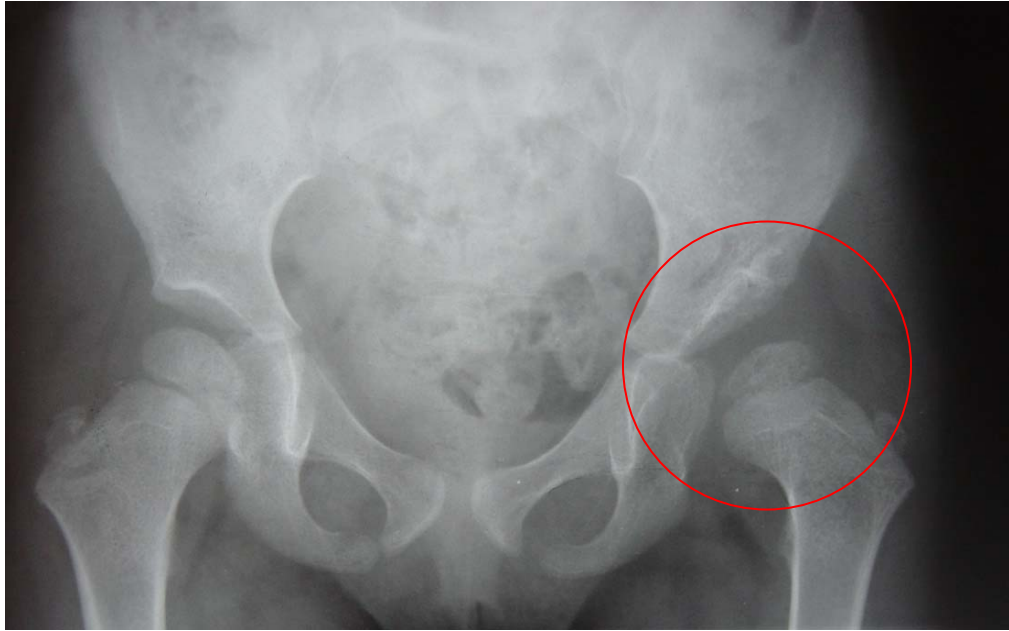


Figure 3.5.2.3 34 Months of age – no AVN, but poor acetabular remodelling
ONCEA 8° (ONCEA/AI 0.21) (Group B)



Figure 3.5.2.4 40 Months of age – left acetabulum still not remodelling well



Figure 3.5.2.5 46 Months of age – poor left acetabular remodelling



Figure 3.5.2.6 52 Months of age – post Salter osteotomy, pins removed



Figure 3.5.2.7 4.5 Years of age – follow-up, good acetabular cover



Figure 3.5.2.8 10.7 Years of age – final follow-up – good outcome

An excellent outcome occurred in this patient. A late successful closed reduction and the secondary procedure performed slightly earlier than normal (at four years of age), allowed an extra year for remodelling of the acetabulum. The group B ONCEA gave her a 60% chance of requiring a secondary procedure and a 65% chance of having a Severin I or II at final follow-up – both of which she had (See table in conclusion). However, the question remains whether a secondary procedure, performed 16 months earlier at the time of her ONCEA measurement, would have improved her long-term outcome.

Case 3.5.3

Female.

Unilateral left sided DDH.

Presented at four months of age.

Followed up till six years.

Successful closed reduction at six months.

ONCEA 20° (ONCEA/AI 0.77) at eight months (group A).

No secondary procedures.

Excellent final outcome – no AVN, Severin class I and McKay group I.

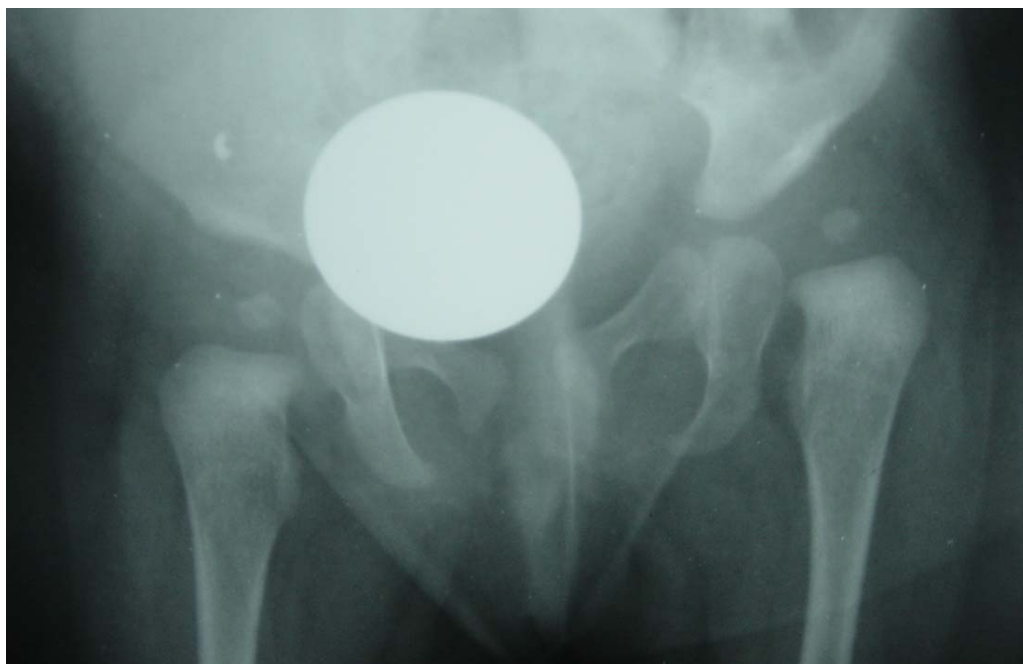


Figure 3.5.3.1 4 Months of age – first presentation, left sided DDH

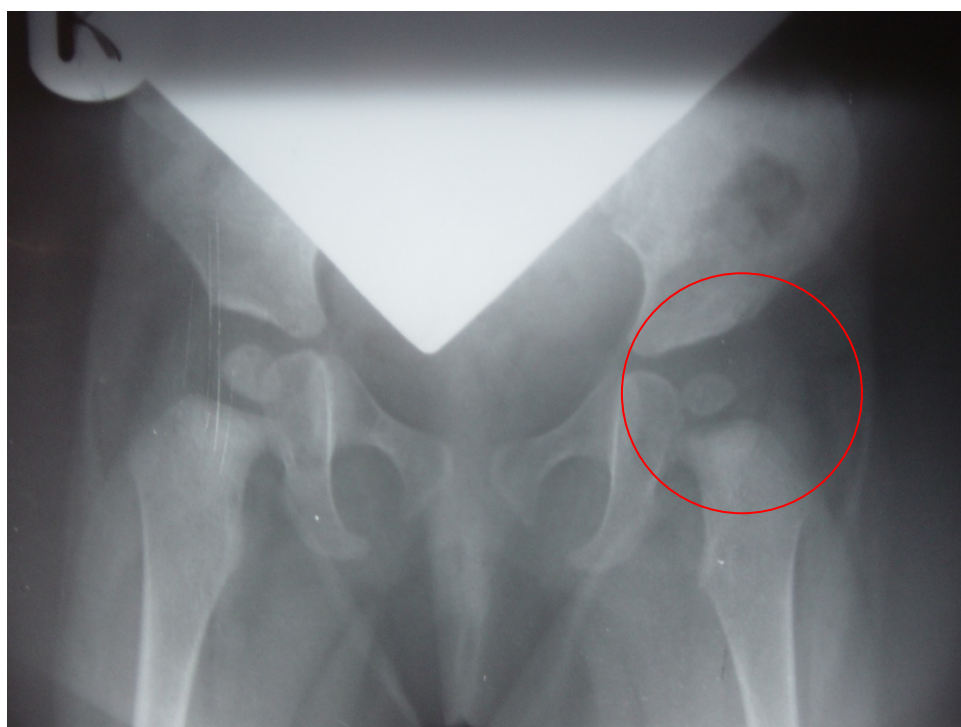


Figure 3.5.3.2 8 Months of age – post-reduction, POP removed

ONCEA 20° (ONCEA/AI 0.77) (Group A)



Figure 3.5.3.3 11 Months of age – acetabulum developing well, no AVN

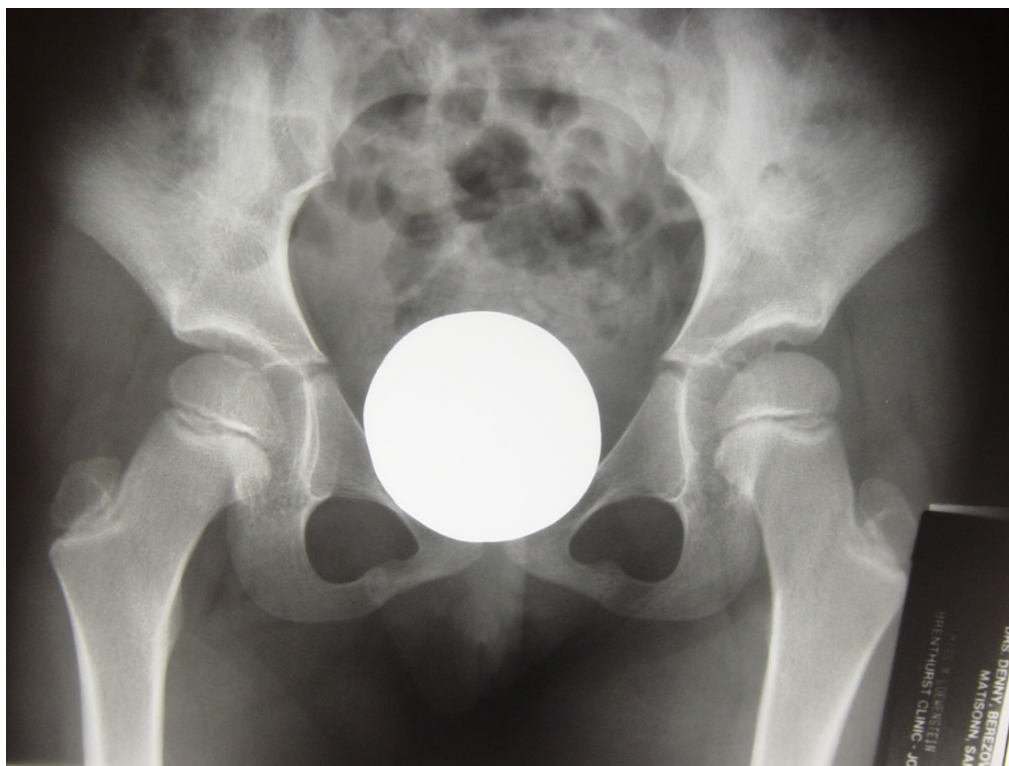


Figure 3.5.3.4 6 Years of age – final follow-up – excellent outcome

The excellent outcome in this case is predicted by the ONCEA of 20° (CEA/AI 0.77) (group A) and by the fact that the reduction was closed, no secondary procedure was required and no AVN developed.

Case 3.5.4

Female.

Bilateral DDH.

Failed Pavlik harness.

Bilateral successful closed reductions at 13 months.

Right ONCEA -6° (ONCEA/AI -0.21) at 21.5 months (ONCEA group B / ONCEA/AI group C)

- No secondary procedures performed on right.
- Right excellent outcome at 15 years (No AVN, Severin I, McKay I).

Left ONCEA -14° (ONCEA/AI -0.41) at 21.5 months (group C)

- Left Salter osteotomy at 5.5 years.
- Left poor outcome at 15 years (AVN IV, Severin III, McKay I).

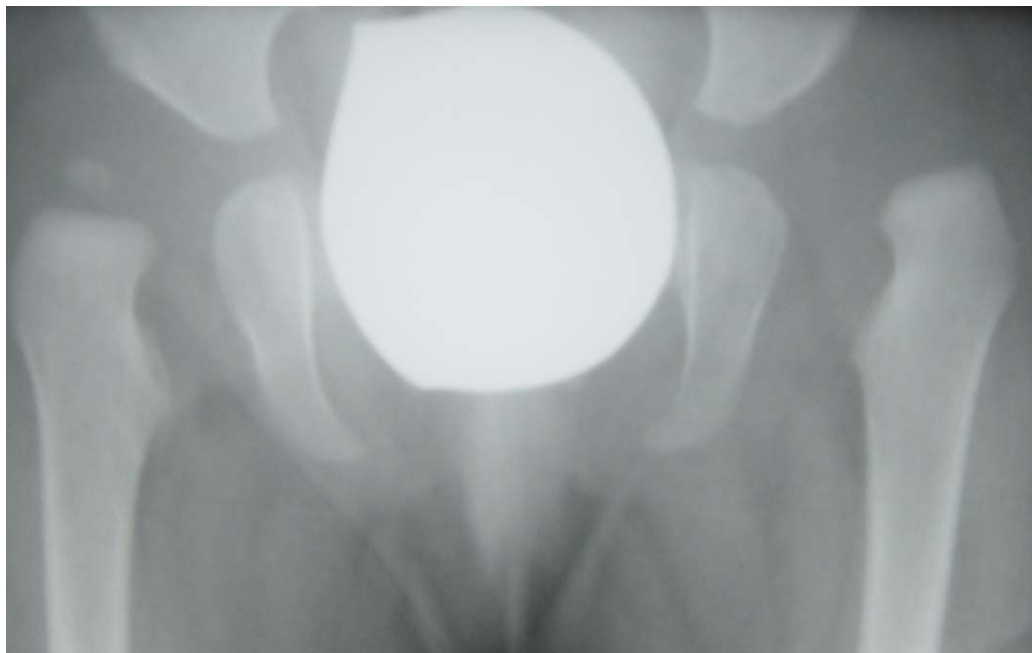


Figure 3.5.4.1 Bilateral dislocated hips, 9.5 Months of age – failed Pavlik harness



Figure 3.5.4.2 Post-bilateral reductions – 13 months of age

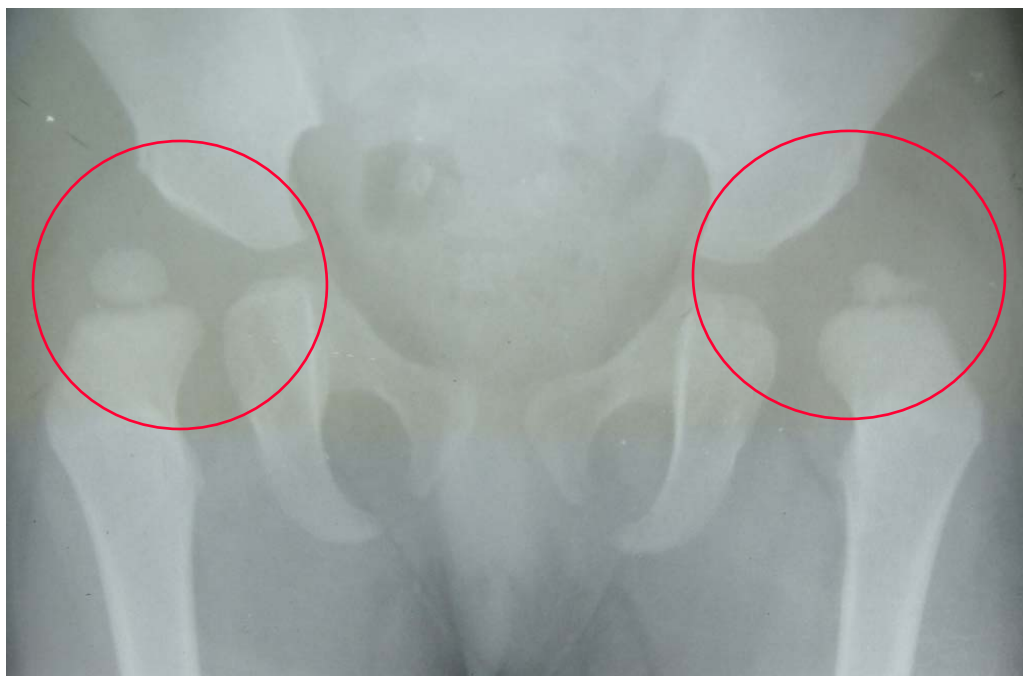


Figure 3.5.4.3 21.5 Months of age

Right ONCEA -6° (ONCEA/AI -0.21) (ONCEA group B / ONCEA/AI group C)

Left ONCEA -14° (ONCEA/AI -0.41) (group C)



Figure 3.5.4.4 2 Years of age – Bilateral subluxation; broken Shenton's lines



Figure 3.5.4.5 5 Years 6 Months of age

Left AVN group IV and poor acetabular development. Right hip developing well



Figure 3.5.4.6 5 Years 8 months of age, post-left Salter osteotomy. Right hip developing well



Figure 3.5.4.7 12 Years of age – left acetabular development inadequate



Figure 3.5.4.8 Final follow-up 15 years of age

Right excellent outcome at 15 years (No AVN, Severin I, McKay I)

Left poor outcome at 15 years (AVN IV, Severin III, McKay I)

The excellent outcome on the right side can be attributed to the successful closed reduction and no need for a secondary procedure. On the left the poor outcome may be attributed to the group C ONCEA and Salter osteotomy only done after five years of age. Performing a secondary procedure at 21.5 months may have improved the outcome of this case, when the ONCEA was -14° . The acetabulum would have had more time to remodel and may have resulted in a better outcome.

4.0 DISCUSSION

In his review of the natural history of DDH, Weinstein² emphasized the poor outcome of patients with residual subluxation. Untreated cases of complete dislocation have a much more variable outcome, ranging from little functional disability to complete incapacitation. The natural history in complete dislocation is determined by two factors: presence or absence of a false acetabulum and bilaterality. The natural history of a subluxed hip (broken Shenton's line) is poor.

Wedge and Wasylenko⁴⁴ found that patients with severe subluxation present with symptoms in the second decade of life, moderate subluxation presents during the third or fourth decade and minimal subluxation presents around menopause. With subluxation, Weinstein found the mean age at presentation for females is 36.6 years and for males is 54 years. Degenerative radiographic changes followed approximately 10 years later. Progression is rapid once symptoms begin.²

Crawford et al found similar outcomes in a group of 20 untreated dislocated hips with DDH, followed till an average of 40 years. As a result, they treat patients older than six years with bilateral DDH or nine years with unilateral DDH with great conservatism.⁴⁵

The management and outcome of DDH in this group of 133 hips has been described. The outcome has been recorded using three classification systems: AVN (Kalamchi and MacEwan), acetabular development (Severin) and clinical outcome (McKay).

The aim of this study was to assess the relevance of early subluxation (within six months of POP removal, following reduction), to determine prognosis and the need for secondary procedures (immediately or at five years).

Severin's classification is the most widely used system for grading the final radiographic outcome of DDH. It was initially used by Severin⁴⁶ in a personal series as a method of prognostication using six classes of progressive dysplasia, subluxation and redislocation after treatment. Good inter-observer reliability is crucial to any classification system's reproducibility and this has been a criticism of the Severin classification system. Ali et al⁴⁷ looked at this and concluded that the inter-observer reliability was poor for a variety of reasons. The method of CEA measurement affected reliability. They assessed subluxation as being interpretive. The age of the patient also affected reliability: Severin felt his system was valid from 4.5 years whereas Ali et al felt it more reliable after 6 years of age. (The current series used age six at final follow-up as minimum.) The intra-observer reliability was good in the same series. It was concluded that the same observer comparing treatment modalities in the same study will produce valid results and conclusions. This is what was done in the current study with confirmation from the supervisors in a sample of cases.

In a review of the reliability of the Severin classification by Ward et al,⁴⁸ unacceptably low levels of intra- and inter-observer reliability were found. They found that too much subjectivity resulted in an insufficiently reproducible assessment and therefore questioned the validity of this classification system.

Severin⁵ explored the development of the joint following closed reduction in 115 hips. He found that in most hips immediately following a closed reduction with the use of an arthrogram, soft tissue is interposed between the femoral head and the acetabulum. This soft tissue barrier is eventually overcome if the head is kept against the acetabulum. The soft tissue interposition had no bearing on outcome. Reduction ensures

acetabular development. Open reduction should rarely be done. He did not use radiological measurements in his study as most of his work utilized the arthrogram.

In a long-term follow-up study, Smith et al⁴⁹ concluded that the best predictor for a normal hip at final follow-up is an initial perfect reduction. They used the position of the head relative to a grid superimposed on Hilgenreiner's line to evaluate the adequacy of reduction. From this they determined the h/b ratio and c/b ratio: 'h' is the vertical distance from the superior-most point of the femoral neck and Hilgenreiner's line; 'b' is the distance from the centre line to Perkin's line (outermost border of acetabular roof); and 'c' is the horizontal distance from the centre line to the medial-most edge of the femoral neck. $c/b > 1$ implies hip dislocation and h/b will be negative if above Hilgenreiner's line. These measurements are shown in Figure 4.1. Only 11/75 hips were normal at final follow-up – of these 7/11 were perfectly reduced initially.

In the current study patients were followed up regularly after reduction and removal of POP, to monitor progression of the ONCEA. The 'worst ONCEA' within six months of POP removal was measured to determine the position of the femoral head to predict outcome, as opposed to the more complicated method of measuring the position of the femoral head using the h/b ratio. The ONCEA did predict the need for secondary procedures and final outcome.

Brougham et al⁵⁰ also found the best predictor for acetabular development after closed reduction was the h/b ratio as shown in figure 4.1. The AI was not predictive of outcome in their study. The acetabulum developed in their series until the mean age of five years (range 17 months to eight years) – this was one of the reasons that six years was the cut-off age at final follow-up in the current study.

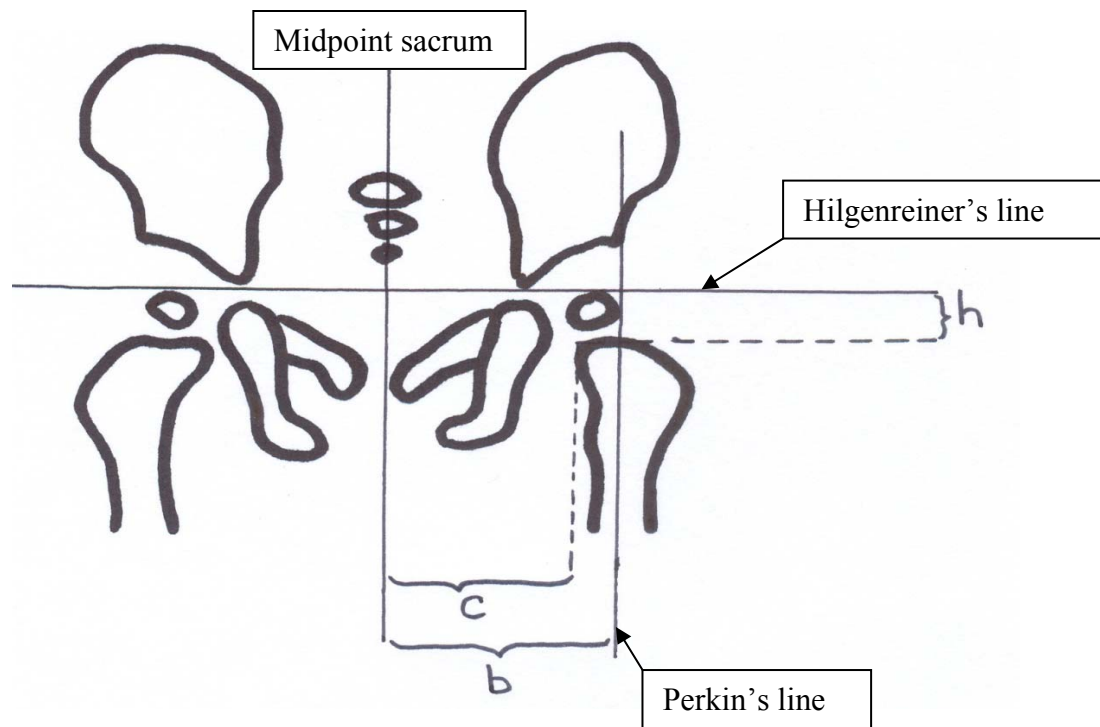


Figure 4.1 Smith's h/b Ratio

Chen et al⁵¹ studied 75 hips with DDH. They found the best predictor of success in unilateral cases was the centre head distance discrepancy ratio (CHDD) measured at one year post-reduction. The method is shown in Figure 4.2. 96% of cases with a CHDD less than or equal to 6% had satisfactory results whereas 78% with a CHDD greater than 6% had unsatisfactory results. They also found that age at reduction and improvement in AI in the first year following reduction are important predictors of outcome. This method utilizes the centre of the femoral head at an earlier age than recommended for measuring the CEA. The only limiting feature of this measurement is that it can only be used for patients with unilateral DDH – in our study 32/101 patients had bilateral DDH. This method is similar to what the current study did in that it also approximated the centre of the femoral head to reach an approximation of the CEA and thence the 'worst CEA' after removal of POP.

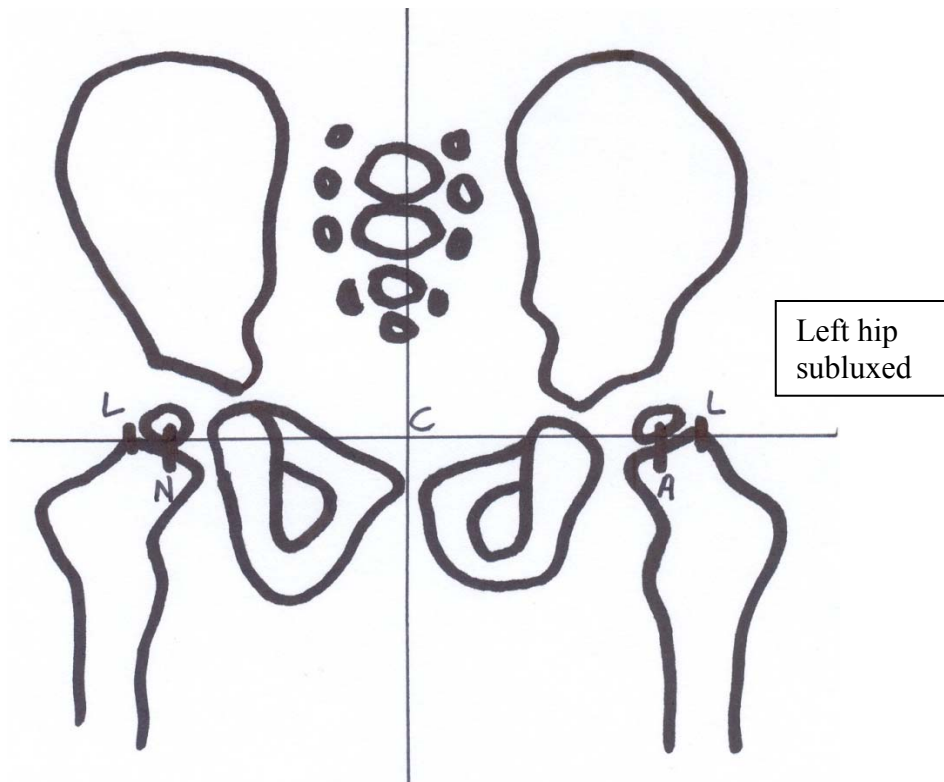


Figure 4.2 Centre Head Distance Discrepancy Ratio = $(CA - NC)/NC \times 100\%$. The right hip is normal but the left hip is subluxed

Kim et al³⁷ studied 32 hips with DDH. Mean age at closed reduction was 15.4 months. They confirmed the above findings of Chen et al⁵¹ using the CHDD and added that if the sourcil was angulated upward, early secondary surgery was recommended to prevent residual acetabular dysplasia.

Malvitz et al³⁶ studied a group of 152 congenitally dislocated hips, reduced at an average age of 21 months and followed up to an average of 31 years; and found that patients with a growth disturbance of the proximal femur or subluxation after reduction were able to function well for many years despite poor radiographic results. Function, however, deteriorated with time and the prognosis for these patients remained guarded.

Huang et al⁵² compared non-operative and operative treatment of DDH in 49 hips of walking age (13 – 17 months) and concluded that these patients could be safely treated using open reduction and simultaneous Salter osteotomy. The current study would partly contradict these findings and recommend that a closed reduction should always be attempted before progressing to an open reduction, even if the patient requires a secondary procedure. If the patient has a ‘severe or mild subluxation’ within six months of POP removal, an early secondary procedure can be performed. If the patient has no subluxation within six months of removing the POP, she can then be monitored until about five years of age when an acetabular osteotomy can safely be performed if the AI $\geq 28^\circ$.²⁹

Luhmann et al⁵³ found that closed reduction should be done as soon as the patient can be safely placed under anaesthesia (i.e: before the appearance of the ossific nucleus). They investigated 153 hips, with a mean age at reduction of eleven months and mean follow-up of seven years and two months. Waiting for the ossific nucleus did not improve outcome. The age at reduction, type of reduction, previous treatment with a Pavlik harness, use of preliminary traction, concomitant procedures and failure of a primary closed reduction were not associated with the development of AVN at final follow-up. This approach was taken in the present study – all hips were reduced irrespective of whether an ossific nucleus was present.

In contrast, Clarke et al,⁵⁴ in a prospective study of 50 hips with DDH, concluded that the presence of the ossific nucleus at the time of reduction was an important factor in preventing AVN, and they would wait for its appearance before attempting reduction.

The upper age limit for treatment in the current group of patients is similar to the literature. One study showed good medium-term results after treating patients between the ages of four and 11 years with an open reduction and simultaneous femoral shortening.⁵⁵

Rosen et al⁵⁶ showed that the Tonnis grade of dislocation on the initial radiograph had the most significant predictive value for success of treatment. The Tonnis grade can be assessed if the clinician has easy access to the Tonnis tables, using the rather complicated method proposed by Tonnis. The aim of the current study was to find a simpler and more practical method to predict outcome – i.e: the ONCEA (or associated ONCEA/AI) soon after removal of the POP following reduction.

Gotoh et al⁵⁷ looked at acetabular development after closed reduction in 63 hips. 86% of patients with a CEA less than 8° and an AI greater than 26° at five years of age were eventually classified with Severin groups III and IV at skeletal maturity. None of these patients underwent a secondary procedure. They did not measure the CEA before five years of age in their population. In our study the ONCEA was classified into one of three groups (severe subluxation, mild subluxation and reduced) and used at a younger age (within six months of POP removal) in order to predict outcome earlier. Our grouping correlates well with their 8° cut-off, as the ‘mild subluxation’ and ‘reduced’ groups were differentiated at 9°.

Albinana et al²⁹ explored acetabular dysplasia following reduction and the need for secondary procedures. They reviewed 72 hips reduced at a mean age of 16 months (range 1-46). At final follow-up 65% were Severin I or II and 35% were Severin III or IV. At 40 years 21% had had a total hip replacement, which was predicted for by the Severin grade. The older the patient at reduction, the worse the Severin score. They also found that the larger the AI between the ages of two and seven years, the greater the chance of treatment

failure. In hips with residual dysplasia, the AI failed to improve between four and five years after reduction. Authors differ regarding the indications for secondary acetabular procedures – subluxation or dislocation, age at reduction, incongruity, intra-operative stability, anteversion, poor cover or residual acetabular dysplasia. Albinana et al recommend operating if the AI is greater than or equal to 28° at four years after reduction, to ensure the lowest possible misclassification rate. If one waits seven years after initial reduction, a secondary procedure should be performed if the AI is 25° or more.

The current study aims to ensure early cover to maximize acetabular remodelling by identifying those patients who would benefit from an early secondary procedure (i.e. mild or severe subluxation within six months of POP removal).

The reliability and reproducibility of the CEA and AI were discussed in the introduction under radiographic evaluation (1.5). Values were followed up by the main author (GBF) and samples were checked by the project supervisors to improve the reliability and reproducibility of results.

The article by Brougham et al⁵⁰ showed that there was a 6° inter-observer error in measuring the CEA. By dividing the ONCEA into three groups ($\leq -10^{\circ}$, -9° to 9° and $\geq 10^{\circ}$), this study has proved that it can be a reliable method of measurement at an early age (mean age 24.1 months in this series). The ONCEA can thus be used as an early prognostic and decision-making tool in deciding which patients may benefit from an early secondary procedure.

The current study could not prove that age at reduction had any bearing on final outcome.

Patients with teratological DDH have been shown to have a consistently poor outcome.² These patients were excluded from our study.

There was an association in the current group of patients between open reduction and ‘significant’ AVN, but this was not explored further in this paper as the focus was on the ONCEA to predict outcome and the need for a secondary procedure. This part of the research was presented at the annual SAOA Conference in Durban, September 2006.

Subluxation after treatment is associated with a poor outcome and has been shown to be associated with the need for early total hip replacement.²

The effect of secondary procedures on final outcome is difficult to assess in this group of patients as the mean age at final follow-up was 12.4 years (range 6 – 26.3 years). As discussed above, the literature regarding secondary procedures shows an association with a better outcome if these procedures are done for the correct indication and in a timely fashion.²

Kitoh et al¹⁶ explored a variety of factors that would predict the outcome of treatment of DDH. They reviewed 45 hips that were treated with overhead traction for DDH without additional procedures at an average age of nine months and followed up to an average age of 17 years. They found that the AI at four years and the CEA at five years after reduction were the earliest predictors of final outcome. The need for acetabuloplasty would be considered using these measurements at four and five years post-reduction respectively. They also found a poor outcome associated with bilateral DDH and poor acetabular cover following overhead traction reduction. The current study is different in that our patients had a formal reduction. The current study also had a much larger sample size – 133 hips. In our study the patients

presented later than in this study – with a mean age at closed reduction of 14.6 months and 22.2 months for open reduction.

The ONCEA as an early prognostic factor in the management of DDH patients has not been used in the literature for patients undergoing closed or open reductions.

The ONCEA was recorded and divided into one of three groups – A, B and C. The ONCEA was used as a prognostic factor to predict the final outcome of these patients and the need for an early secondary acetabular procedure. Table 4.1.1 shows that in group C only 54% had a Severin class I or II at final follow up, despite 85% eventually requiring a secondary procedure. The ratio of the ONCEA/AI was also divided into three groups. There was also a statistically significant association with group A and an excellent outcome, as shown in Table 4.1.2.

Table 4.1.1 Summary table of ONCEA and outcome

	ONCEA Group A (76 Hips)	ONCEA Group B (44 Hips)	ONCEA Group C (13 Hips)
Severin Class (p=0.0001)	79% I&II	64% I&II	54% I&II
McKay Group (p=0.012)	79% I&II	79% I&II	62% I&II
Secondary Procedures (p=0.016)	42%	59%	85%

Table 4.1.2 Summary table of ONCEA/AI and outcome

	ONCEA/AI Group A (47 Hips)	ONCEA/AI Group B (65 Hips)	ONCEA/AI Group C (21 Hips)
Severin Class (p=0.0011)	83% I&II	71% I&II	48% I&II
McKay Group (p=0.0279)	82% I&II	77% I&II	65% I&II
Secondary Procedures (p=0.0002)	29%	60%	81%

5.0 CONCLUSIONS

The null hypothesis has been proved (if the hip subluxes after reduction and is only observed, many of such patients will require a secondary procedure at five years to obtain a good result but will not necessarily require further attempts to reduce the hip). After formal reduction, patients with subluxation within six months of POP removal (ONCEA and ONCEA/AI groups B and C) generally did poorly at final follow-up, despite secondary acetabular procedures being performed at a mean age of 58 months.

This study confirms the findings of the literature reviewed in the discussion above: subluxation results in a poor outcome. The various methods described above to determine adequacy of reduction are often complicated and can only be used for unilateral cases. The ONCEA or ONCEA/AI, measured within six months of POP removal, is a simple way to determine outcome and the need for an early secondary procedure, with the understanding that an early secondary procedure will increase femoral head coverage and theoretically improve remodelling potential and final outcome.

Serial radiographic follow-up is essential in patients with DDH, especially to determine the lowest numerical value of the ONCEA and ONCEA/AI within six months of POP removal. Serial radiographs are also important to check that the reduced hip does not redislocate and to determine the final Severin class and the final Kalamchi and MacEwan AVN group. From this study, it seems reasonable to recommend doing an X-ray at the time of POP removal and then at three months and six months to determine the ONCEA and ONCEA/AI.

The ONCEA and ONCEA/AI within six months of POP removal can be used to predict outcome. These values can also be used to decide whether an immediate secondary procedure should be performed, or whether it is safe to wait till four years after reduction (about the age of five years) and measure the AI, before performing a secondary acetabular procedure. This approach is similar to that of Salter et al. They would do an open reduction and simultaneous Salter osteotomy on a child with a dislocated hip (DDH) older than 18 months of age with good long term follow up.^{31 32}

With severe subluxation (ONCEA and ONCEA/AI group C), an immediate secondary acetabular procedure should be considered. In this group only 48 – 54% of patients had a Severin class I or II, and 62 – 65% had a McKay group I or II at final follow-up (mean age 12 years), despite 81 – 85% having had a secondary procedure at a mean age of 58 months.

Mild subluxation (ONCEA and ONCEA/AI group B) can be observed till four years after reduction but it must be communicated to parents that the child has a 60% chance of requiring a secondary procedure by the age of five years. In this group, the chance of obtaining a Severin class I or II is 64 – 71% and of obtaining a McKay I or II is 77 – 79% at final follow-up (mean age 12 years).

Reduced hips (ONCEA and ONCEA/AI group A) will usually do well. 29 – 42% will require a secondary procedure around five years of age. 79 – 83% will obtain a class I or II Severin or McKay score at final follow-up (mean age 12 years).

The ONCEA at the young ages (mean age 24.1 months) for which it was measured in this study has been reliable in predicting outcome. The method of measurement as described in the text ensures that a simple, reliable and reproducible measurement can be used to predict outcome and determine the need for early secondary acetabular procedures.

This thesis has demonstrated the importance of the ONCEA and associated ONCEA/AI measured within six months of POP removal, following closed or open reduction under general anaesthesia. It is hoped that it will be used by fellow orthopaedic surgeons as a guide to predict outcome and facilitate decision-making regarding the timing of secondary acetabular procedures.

The ONCEA and ONCEA/AI should be used in combination to increase the reliability of the measurements taken. An early secondary procedure should be performed for ONCEA or ONCEA/AI group C. Group B should probably also undergo an early secondary procedure, after thorough consultation with the parents. Group A should be followed up closely and the need for secondary procedure assessed at the age of five years. If $AI > 28^\circ$ at five years of age, a secondary procedure should then be performed.

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