ARTHRODIASTASIS VERSUS SALTER OSTEOTOMY IN TREATMENT OF LEGG- CALVÉ-PERTHES DISEASE: SHORT TERM RESULTS

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Abstract

Background: To this day, no consensus exists regarding the most effective therapy during the active phase of Perthes' disease, and no therapy has statistically substantially improved the course of Perthes' disease compared to other therapies.

Objective: This combined retrospective prospective study aimed to compare the clinical and radiological results of salter innominate osteotomy as a containment therapy versus arthro-diastasis as a mean of joint mechanical protection in patients with Legg-Calve-Perthes (LCP) in aspects of controlling the outcome of the disease progression.

Patients and methods: A total of 29 patients (31 hips), six-year or older of both genders with LCP disease in the stages of necrosis or revascularization, were enrolled. Patients were submitted to either Salter innominate osteotomy (SO) (n=16) or hip arthrodistraction (HA) (n=15). At the final follow-up, patients were evaluated both clinically according to Harris hip score and radiologically according to Caput Index and Epiphyseal quotient.

Results: The mean follow up was 22.81±7.70 months for both groups (21.25±7.49m for SO, 24.47±7.83m for HA). The clinical outcome in this study, based on HHS, showed no significant difference between the study groups. No patient reported residual pain in the hip. All patients could sit cross-legged and were able to squat. Radiographically, the collected data from final follow up radiographs were compared and found no significant difference between study groups in terms of CI of involved hips (P=0.374) however, there was a statistically significant difference between both groups when it came to epiphyseal quotient (EQ in favor of HA (P=0.048).

Conclusion: Both treatment modalities are valid options for altering the outcome of the disease. Despite similar final clinical and radiological results, the arthrodistraction process had a better result regarding EQ when compared with the innominate osteotomy which indicates better sphericity of the involved hips at final follow up.

Keywords: Arthrodiastasis, Salter innominate osteotomy, Perthes's disease, Caput index, Epiphyseal quotient

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1. INTRODUCTION

In 1910, Legg (United States), Calvé (France), and Perthes (Germany) simultaneously identified a juvenile hip disorder as an ambiguous alteration, pseudo-coxalgia, and juvenile deforming arthritis, which constitute the picture now known as Legg-Calve-Perthes disease (LCPD). (1)

The disorder is self-limiting and is caused by varying degrees of ischemia of the femoral head, which leads to bone necrosis. Although numerous hypotheses have been proposed to explain inadequate blood flow to the femoral head, including genetic predisposition, environmental exposures, and/or socioeconomic variables, the exact explanation remains unknown. (2) The median age at diagnosis is six years, with a range of four to twelve. The majority of afflicted individuals are boys aged 4 to 8. The prognosis for disorders that manifest beyond the age of eight is often dismal.

Patients with LCPD frequently report hip and/or knee pain as well as a reduction in their range of motion, particularly during internal rotation and hip abduction. The initial symptom of LCPD on radiographic evaluation is the ossification nucleus of the femoral head contracting and the joint space enlarging. The second symptom is a subchondral fracture (Caffey's sign), and the third sign, which designates avascular necrosis, is a rise in the radiopacity of the femoral head. From that point on, the repair process generates a heterogeneous image, depending on the areas of revascularization and new necrosis outbreaks.

Several factors, such as lateral column involvement, the degree of epiphyseal involvement, femoral head lateralization (subluxation), age of onset, disease stage, and treatment method, have been shown to affect the course of the disease.(3-5)
By guarding the femoral head mechanically, the current treatment for Legg-Calvé-Perthes disease aims to avoid hip deformity and future joint degeneration. The foundation of this protective function is conserving the plastic epiphysis in the acetabulum, which can be achieved by either conservative or surgical means.
Salter articulated the concept of biological plasticity for the first time in 1966.(6) According to this notion, a normal or near-normal femoral head will form if the femoral head is kept in the acetabulum during the repair process. In light of this information, containment therapy has become a crucial component of Perthes treatment. Surgical containment therapy (pelvic, femoral, and combination osteotomies) and non-surgical containment therapies have been discussed (abduction traction, orthoses). Unfortunately, neither of these treatments reduces pressure on the femoral head nor alters its shape.
Recent research has provided some evidence that distraction stresses applied to the hip joint may be able to protect the femoral head mechanically and encourage bone revascularization.(7-11) Consequently, as it offers a compelling connection between mechanical and biological processes, hip joint distraction may propose an alternate therapeutic choice for patients with Legg-Calvé-Perthes disease.
There is still no consensus regarding the most effective modality to use while the disease is active, and none of them has statistically improved the course of Perthes disease significantly when compared to other modalities.

2. PATIENTS AND METHODS

- **Study design:**

A combined retrospective, using data collected both retrospectively and prospectively from the registry of the orthopedic pediatric and deformity units at Mansoura University between Jan 2018 and Nov 2020, and a prospective cohort study; which included patients who met the criteria and visited our out-patient clinics between Nov 2020 and Nov 2021.

- **Patients:**

Patients included in our study were presented with Perthes disease with an age above 6 years of both genders with at least two of the following findings at time of presentation; Herring lateral pillar classification type B or C or B/C, moderate to severe restriction of movement, severe pain or shows one or more Catterall head at risk signs.
Patients with the following criteria were excluded; age less than 6 years, Herring classification type A, mild pain or restriction of movement, shows no Catterall head at risk signs or already in the advanced stages with deformed femoral head, fixed adduction contracture, acetabular deformity and hinge abduction. Patients lost in follow up, had less than one-year follow-up or had incomplete data were excluded.

- **Methods:**

At the initial evaluation and according to our protocol of management, a complete clinical was obtained including Age, Sex, timing of complaint, history of previous trauma and history of previous treatment. A preoperative thorough general and local examination for the hip joint has been conducted and Radiographs (supine anteroposterior and frog limb lateral pelvic views) were used to validate each child's diagnosis, and the following parameters were determined based on the radiographs: The disease's stage (necrosis, revascularization, and remodeling), the degree of epiphyseal involvement in the lateral view, and whether or not the femoral head is subluxated are all factors to consider.
Hip subluxation has been specified by a broken Shenton’s line and an increased distance between the acetabulum and the medial intraarticular part of the metaphysis of the femur. For those cases in the revascularization stage, the lateral pillar classification was applied. (12) For patients included in this study, two treatment options were presented to the child’s guardians: hip distraction or pelvic osteotomy. After thoughtful discussion between the guardians and the surgeons, a treatment strategy was devised and written consent was obtained.

- **Surgical technique:**

On a radiotransparent operating table, procedures were carried out with the patient under general or spinal anesthesia. Prior to surgery, the hip was inspected for concentric motion using an image intensifier. Arthrography was performed, if necessary, to assess the degree of containment and rule out the probability of hinge abduction formation and other secondary changes such as labral pathologies, femoro-acetabular impingement.
A bikini incision was used to perform the innominate osteotomy in accordance with Salter's method. (13)The innominate bone was cut with a saw from the sciatic notch to the anterior inferior iliac spine; the entire acetabulum, along with the pubis and ischium, was then rotated anteriorly and laterally, with the symphysis serving as a hinge. The osteotomy is anteriorly opened by the femur's external rotation and flexion. A pair or three thick Kirschner wires were used to secure the autograft made from iliac bone in the osteotomy line. At the musculotendinous junction, the adductor longus and iliopsoas muscles were always lengthened.

During the four weeks following surgery, a pelvi-pedal spica cast or abduction orthosis was used.

For hip distraction, an articulated Ilizarov external fixator was applied to the pelvis and the femur. Before applying the device, a Transphyseal Neck-Head Tunnelling (TNHT) was performed using a C-arm that was always kept perpendicular to the operating table.(14) A Kirschner wire is used as an aiming device, placed over the skin on the anterior aspect of the hip to determine the proper level of the drilling procedure and the proper entry point of the guide wire at the lateral side of the proximal metaphysis of the femur. The affected limb is then rotated medially to position the femur's neck parallel to the ground. A stab wound is made to introduce a smooth 2 mm K-wire, which is subsequently advanced back and forth across the physis, halting just before the subcondral bone as identified by the arthrogram creating multible tunnels.

A flexion extension axis pin was advanced into the femoral head to define the exact center of the hip joint in both Ap and Lateral radiographs as a reference for hinge positioning. A hinged circular external fixator was preconstructed to save time of surgery. Three Schanz screws of 5 mm in size were inserted into the supra-acetabular area and fixed to 90° arch. Half ring or another arch of same size was applied to the femur using three 5 mm Schanz screws at different planes and levels as much as possible. The frame was connected using articulating hinges referenced by the flexion extension axis pin while the femur is in the optimal degree of abduction. On the table, hip was distracted until widening of the joint was seen under image intensifier until overcorrection of Shenton line by 2-4 mm. An extension rod was placed anteriorly to control the timing for flexion/extension of the hip along the hinges achieving what we call a controlled hinged arthrodiastasis device.

Associated Soft tissue release was decided for each patient individually according to his/her condition. An adductor tenotomy was done where the hip and knee are flexed and abducted, and the adductor longus tendon is palpated at the groin and cut either mini-open using diathermy or percutaneously with a number 15 blade.

- **Follow up:**

For pelvic osteotomy, hip abduction was maintained for 4 weeks in a pelvi-pedal spica cast or abduction orthosis. Rehabilitation was started by the end of the 4th week and full load was applied at the end of the tenth week.

For hip distraction, the patients were encouraged to walk with partial weight bearing using two elbow crutches immediately after the operation. The extension rod was left in place for the first week then the patient was educated to disassemble a single nut to allow for hip flexion on a regular pattern three times daily then assembling the extension rod again in place to protect the hip from flexion deformity.

At weekly intervals, the distraction was checked and radiographs were taken, if necessary. The hip distractor device was removed when ossification of the lateral pillar had occurred.

For both groups; Preoperative and postoperative clinical evaluation is done according to the Harris Hip Score (HHS).(15) Results were interpreted as following: <70 = poor result; 70–80 = fair, 80–100 = good to excellent.

Pelvic radiographs in both the anterior-posterior and frog position were taken early in the postoperative period, at three, six and twelve months postoperatively and then yearly after. The preoperative and final postoperative radiographs were used to obtain the change in Caput Index and Epiphyseal Quotient calculation. (16)

The anatomical center of the femoral head was determined by positioning the femoral head within an ideal sphere in both AP and lateral X-rays. D is the femoral head's largest diameter. The minimum radius (s) is calculated between the center of D and the surface of the femoral head. The D and s values represent the average of the values in the two views. Using the caput index (CI) = ([s × 2]/D), the sphericity of the femoral head was determined. (190) The epiphyseal quotient (EQ) is calculated from the X-rays. It is the ratio of the epiphyseal index of the involved head with that of the uninvolved head. The epiphyseal index is calculated by the greatest height of the epiphysis divided by its width. The EQ was graded as good (>60%), fair (40–60%) and poor (≤40%). (16)

For retrospective cases, the following data of the patients were collected from registry: Patients' demographics, clinical parameters at time of presentation and final follow up according to HHS and radiological evaluation based on femoral head change in Caput Index and Epiphyseal Quotient. (16)

- **Ethical consent:**

Written informed consent was obtained from patients' guardians of all subjects of the study. The study was approved by Mansoura Medical Research Ethics Committee. Confidentiality was taken in consideration by using code number or letter which refers to the name and address of the patient, hiding the names and addresses of patients when using their reports and investigations and using the results of investigation in the scientific publishing.

- **Statistical analysis**

The statistical analysis was conducted using version 18 of SPSS software (SPSS Inc., PASW Statistics for Windows version 18). The collected data were coded, processed and analyzed and the appropriate statistical tests were used when needed. A p-value below 0.05 was considered significant.

3. RESULTS

I. Demographic data

As shown in the flow chart in (Fig.1), Over a period of 3 years, between 2018-2021, 86 patients presented to our institution with Perthes disease. Of these 34 were found to be younger than 6-year-old and therefore were excluded from our study. Besides, twelve patients presented with sequalae and received a different treatment strategy based on their clinical and radiological assessment. Another eleven patients were not included because they were lost in follow up or had incomplete data.

Based on the aforementioned criteria, a total of 29 patients (31 hips) were enrolled in our study and submitted to one of two different treatment plans either Salter innominate osteotomy (SO) (14 patients /16 hips) or hip arthrodiastasis (HA) (15 patients /15 hips).

The mean age at presentation was 7.52±1.54 years (7.16±1.26 for SO and 7.90±1.75 for HD). Patients involved in this study were from both genders with only two female patients, one in each group. The statistical analysis showed that both groups were matched and comparable in terms of gender (P=1.0) and age at presentation (p=0.184).

In total, fifteen hips were on the right side and sixteen hips on the left with right to left side ratio 0.9:1 (1.2:1 for SO, 0.66:1 for HA). Two cases in SO group were bilateral hence the number of patients to hips (14 patients with 16 hips).

According to Herring (lateral pillar) classification, 3 patients (9.7%) belonged to Stage B (n=1 for SO (6.2%), n=2 for HA (13.2%)), 9 patients (29%) belonged to Stage B/C (n=5 for SO (31.2%), n=4 for HA (26.7%)) and 19 patients (61.3%) belonged to Stage C (n=10 for SO (62.5%), n=9 for HA (60%)).

All patients were successfully followed up, with an average follow-up of 22.81±7.70 months for both groups (21.25±7.49m for SO, 24.47±7.83m for HA). The statistical analysis also showed no significant differences in the lateral pillar classification subgroups between the two study groups (P=0.792), side of involvement (P=0.366) or follow-up time (p=0.252), making both groups comparable.

II. Preoperative data of study groups:

As shown in table (1), the calculated preoperative HHS had a mean of 63.50±4.16 for SO group and 62.9±3.45 for HA group with no statistically significant difference between the two groups (P=0.684). Radiographically, the epiphyseal quotient (EQ) of involved hips had a comparable mean for both groups (SO=41.56±7.45%, HA=39.73±9.92%). Also, mean caput index (CI) of affected hips was comparable (SO=54.38±12.33, HA=53.67±13.28).

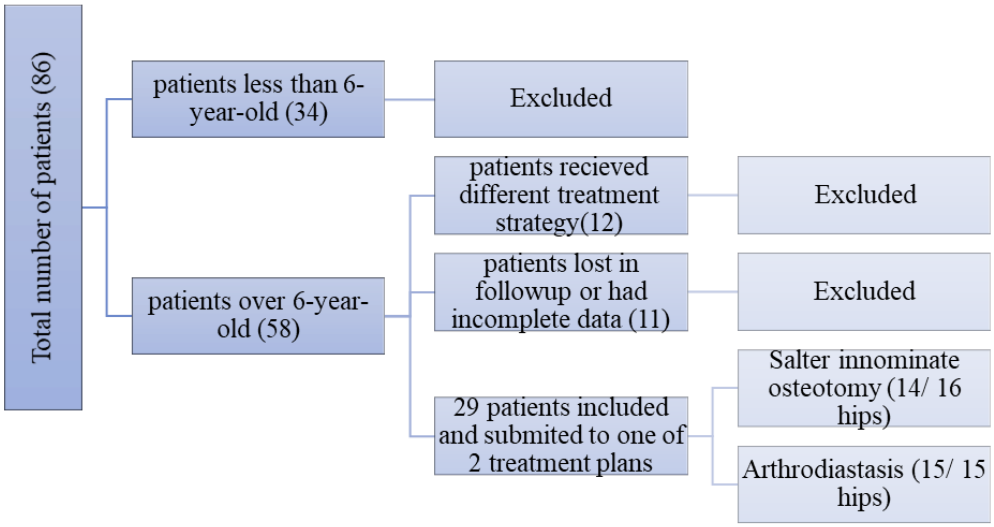

FIG (1): Flow chart of patient selection according to our study criteria.

Table (1): Comparison of preoperative mean data between studied groups

	Salter innominate osteotomy n=16 (Mean±SD)	Arthrodiastasis n=15 (Mean±SD)	Test of significance student t test
HHS	**63.50±4.16**	**62.9±3.45**	**t=0.411 p=0.684**
EQ	**41.56±7.45**	**39.73±9.92**	**t=0.583 P=0.564**
CI involved	**54.38±12.33**	**53.67±13.28**	**t=0.154 p=0.879**

III. Final outcome data of the study groups:

During the follow up period, the average time for osteotomy union in SO group was 8.65±1.25 (range 6-10 weeks). On the other hand, the distraction device remained implanted for an average of 4±2.6 Months (range 2.5-5 months).

The clinical outcome in this study, based on HHS, showed no significant difference between the study groups. No patient reported residual pain in the hip. All patients could sit cross-legged and were able to squat. Two patients had the restriction of terminal abduction and internal rotation, one in each group. No one had a fixed deformity of the hip.

Radiographically, the collected the data from final follow up radiographs were compared and found no significant difference between study groups in terms of CI of involved hips (P=0.374) however, there was a statistically significant difference between both groups when it came to epiphyseal quotient (EQ) in favor of HA group which indicates better sphericity of involved hips at final follow (P=0.048).

IV. Complications of the study groups:

In the pelvic osteotomy group, there was one case of superficial infection that required use of local antiseptics and oral antibiotics and then resolved nicely with no further complications. Another patient was submitted to physiotherapy because of restricted hip motion, with an uneventful recovery. One patient had a Trendelenburg gait with relative LLD of 1.74 cm as calculated by clinical measures and scanogram. No patient reported residual pain in the hip. All the patients could sit cross-legged and were able to squat. Two patients had limitation of terminal abduction and internal rotation. Two patients had an early collapse of the opening wedge osteotomy because of early weightbearing against physician instructions although they ended with good results. No other complications were reported. In the arthrodiastasis group, the most commonly encountered complication was pin tract infection (n=7, 46.6%) that was treated with short periods of oral antibiotics. All patients in the HA group, in the postoperative period, were able to partially bear weight from day 1, except in one case, where the child was afraid to walk, despite psychological support. Two patients suffered a broken pelvic screw (13.3%), but it was not replaced because it occurred in the final stage of treatment. One patient had a Trendelenburg gait with relative LLD of 1.5 cm as calculated by clinical measures and scanogram. One patient presented with hip stiffness after the device was removed and was treated with physiotherapy after which a significant improvement occurred in his articular mobility. No cases with fixed hip deformity were reported.

V. Comparison of preoperative and postoperative date of study groups:

Clinical parameters:

The postoperative HHS score improved significantly compared to the calculated preoperative score in both groups, however there was no significant difference between the two groups.

Radiological parameters:

As shown in table (2), the postoperative mean EQ improved significantly compared to the calculated preoperative mean in both groups. On the other hand, there was significant difference between the two groups in favor of HA group in terms of mean EQ and mean change.

Table (2): Comparison of mean EQ between studied groups

		Salter innominate osteotomy n=16	Arthrodiastasis n=15	Test of significance
EQ	Pre-operative	41.56±7.45	39.73±9.92	t=0.583 P=0.564
	Post-operative	62.31±9.36	69.13±9.04	t=2.06 p=0.048*
Paired t test		t=12.36 p<0.001*	t=15.85 p<0.0001*	
Change in EQ		20.75±6.71	29.13±7.12	t=3.37 p=0.002*

After complete follow-up, the final CI of the affected and the normal hip was evaluated, and change in CI of the normal hips was compared to change in CI of the affected hip after surgery for each group. It was found that there was a significant change in the CI on the final follow-up in both groups which showed a good remodeling of the femoral head. However, there was no significant difference between the two groups in terms of mean change in CI of affected hips as shown in table (3).

VI. Factors affecting final outcome:

A Relationship statistical analysis was conducted between the two main variables; age at presentation and Herring grading, and outcome in both groups to detect any statistical significance and found that there was negative correlation, but not statistically significant, between age or Herring grading and HHS at final outcome of involved hips in both

groups. On the other hand, there was a significant relation between age and EQ of hips underwent arthrodiastasis at final outcome with insignificant relation with Herring grading. However, there was no statistically significant relation between age or Herring grading and postoperative EQ of hips underwent Salter osteotomy. Also, there was no statistically significant relation between age or Herring grading and mean change in CI of involved hips in both groups.

Table (3): Comparison of mean change in caput index involved and noninvolved between studied groups:

	Salter innominate osteotomy n=16	**Arthrodiastasis n=15**	**Test of significance**
Mean change in CI involved	**22.06±7.55**	**19.33±7.48**	**Z=0.753 P=0.451**
Mean change in CI non-involved	**2.34±1.43**	**2.47±1.25**	**Z=0.343 P=0.732**
Wilcoxon signed rank test	**Z=3.52 P<0.001***	**Z=3.42 P<0.001***	

4. DISCUSSION

Legg-Calvé-Perthes disease is one of the most researched conditions in paediatric orthopaedics; however, the condition is still inadequately understood and there is substantial disagreement regarding its treatment. Nonetheless, some parameters have attained consensus. First, the majority of authors believe that elder children, particularly those older than eight years old (4) , in cases of lateral pillars B and C (17) and involvement of more than fifty percent of the femoral head are associated with a more severe disease(18) Only cases with a benign natural history or those so severe that preventative treatment would be ineffective should receive nonspecific treatment.(4)

In the period between 2018 to 2021, a total of 29 patients (31 hips), presented to our institution with Perthes disease, were enrolled in our study after exclusion of 34 child who were younger than 6-year-old, 12 patients who received a different treatment and another 11 patients who were lost in follow up or had incomplete data.

Our study was conducted both retrospectively and prospectively, but it was not blinded and was non-randomised. In fact, because we chose not to randomise the study for ethical reasons, the treatment decision was made by the child's parent or legal guardian.

In our study, femoral head morphology was evaluated by Epiphyseal Qoutient and Change in Caput index. Many studies have used Moses index(19) in their studies to quantify the morphology of femoral head. However, it is difficult to measure some femoral heads using Moses index which are not circular enough to fit the outline of the Moses circle as quoted by Dickens et al. Additionaly, our groups of patients were still way from maturity with short periods of follow up which rendered the use of Mose circles, that apply to skeletally mature heads, not possible. To solve this problem we avoided moses circles.(20, 21) Hence, we used CI and the EQ as measureing parameters of the sphericity in our study. Shigeno and Evans(22) reported that femoral head deformation was more significant in AP radiograph than lateral in fragmentation stage. However, Cho et al.(23) stated that in children the femoral head is deformed both in the sagittal and coronal plane. Herring et al.,(12) Fredensborg,(24) Heyman and Herndon,(25) Mose(19) used AP radiographs only. In our study, we considered both the AP and lateral radiographs.

The mean age at presentation was 7.52±1.54 years (7.16±1.26 for SO and 7.90±1.75 for HD) which is relativley lower compared to groups treated by José Batista in his comparative study.(26)

Overall, the clinical outcome in this study, based on HHS, showed no significant difference between the study groups. No patient reported residual pain in the hip. All patients could sit cross-legged and were able to squat. Two patients had the restriction of terminal abduction and internal rotation, one in each group. No one had a fixed deformity of the hip. This was similar to results published by other authors regarding the short-term clinical outcome.(26-28)

Radiographically, the collected the data from final follow up radiographs were compared and found no significant difference between study groups in terms of CI of involved hips (P=0.374) however, there was a statistically significant difference between both groups when it came to epiphyseal quotient (EQ) in favor of HA group which indicates better sphericity of involved hips at final follow (P=0.048). This came to counter the results published by José Batista which suggested that better radiological results were found with the Salter group.(26)

Several studies (7-11, 29) have investigated the efficacy of arthrodistraction in the treatment of Perthes disease, albeit with varying methodologies. Some authors used soft tissue release(29), while others used the non-articulated Ilizarov technique.

(10)Maxwell et al. (7) treated 15 hips with a unilateral articulated external fixator and used a historical series as a control. Although the authors acknowledged that their findings were preliminary and had a number of limitations(7), the approach may be beneficial for patients with Perthes disease. Our final results reflect the same perspective with a little privilege in HA group having better EQ results. The innominate osteotomy group, on the other hand, exhibited fewer difficulties when comparing the two techniques, not only in terms of ultimate results but also when considering the entire treatment course. In reality, the child's daily life after surgery was significantly impacted by the repeated episodes of pin tract infection and pain, the difficulties of moving with an external device that interfered with clothing and social activities, and the difficulty of convincing the child to go outdoors with the device attatched to him. However, we can't ignore the advantages of early walking, shorter periods of hospital stay and durations spent attached to bed in favor of arthrodiastasis when compared to Salter group.

The strength of this investigation is that it was a compartive study that compared two similar populations applying objective methods of patient selection and evaluation. The drawbacks were that the radiological paremeters used in our study don't reflect the end picture of disease outcome in the future and the duration of follow up was short with relatively low number of cases compared to other case series in the literature.(26)

5. CONCLUSION

Both treatment modalities are valid options for altering the outcome of the disease. Despite similar final clinical and radiological results, the arthrodistraction process had a better result regarding EQ when compared with the innominate osteotomy which indicates better sphericity of involved hips at final follow up. On the other hand, complications were a bit lower in the Salter group.

6. STUDY LIMITATIONS

•Despite having prospectively collected data, this study was partly a retrospective series, therefore had the same limitations and biases as all retrospective studies.

•Our current duration of follow-up was short; the mean follow-up approaching 2 years with a 1-year minimum FU.

•The number of patients involved in the study is limited giving sometimes false statistical errors.

•Finally, classification of the results according to end stage methods may give more clear idea about the efficacy of treatment modality.

7. RECOMMENDATION

The number of patients in the study needs to be expanded to get more valid results, besides, longer-term FU, more than 10 years, is needed to approach end results after arrest of the disease process.

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Conflict of interest: Nil.

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