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ORIGINAL PAPER

Moderate and severe SCFE (Slipped Capital Femoral Epiphysis) arthroscopic osteoplasty vs open neck osteotomy—a retrospective analysis of results

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Abstract

Aim We intend to compare the outcomes of arthroscopic osteoplasty with open neck osteotomy for correction of the hip impingement and improvement of hip function in children with moderate to severe healed Slipped Capital Femoral Epiphysis (SCFE). Our aim is to verify if arthroscopic osteoplasty could achieve the same outcome as open procedures.

Patients and methods A retrospective analysis of the hospital hip database retrieved 187 cases of SCFE from 2006 to 2013. We found 12 patients underwent open neck osteotomy and deformity correction for moderate/ severe healed SCFE and ten underwent arthroscopic osteoplasty of the hip. We compared the outcomes between these groups.

Results In the arthroscopy cohort, the mean age at surgery was 15.8 years (range 13–19 years) and mean follow-up was 46.1 months (range 33–66 months). In the neck osteotomy group, the mean age at surgery was 14.6 years (11–20 years) and mean duration of follow-up was 49 months (36–60 months). The outcomes in arthroscopic osteoplasty group vs. open neck osteotomy were as follows: antero-posterior (AP) slip angle 9.2° (0.3°- 28.8°) vs 10.8° (1°–17.9°) ($p = 0.0003$), lateral slip angle 44.8° (36.5°–64.2°) vs 13.5° (1°–28.5°) ($p = 0.00001$), oblique plane deformity 47.1° (40.2°–53.5°) vs 16.7° (1°–28.6°) ($p = 0.0003$), alpha angle 61.88° (52.1°–123°) vs.34.6° (23.2°–45.6°) ($p = 0.0003$), anterior offset 0 mm (0 mm–2 mm) vs. 5 mm (2–13 mm) ($p = 0.0003$), modified Harris hip score (MHHS) 75.5 (58.75–96.8) vs. 90 (86.2–99) ($p = 0.003$), non-arthroplasty hip score (NAHS) 67.12 (18.75–100) vs. 92.1 (81.25–100) ($p = 0.002$), internal rotation 20° (0–20°) vs. 50° (30°–70°) ($p = 0.0002$), respectively.

Conclusion Even though the radiographic correction lagged behind in the arthroscopic group, the functional outcomes achieved did convey the gain of function in this cohort. In carefully selected cases, arthroscopy could be a less invasive procedure which has desirable outcomes.

Keywords Slipped capital femoral epiphysis · Arthroscopic osteoplasty · Open neck osteotomy

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Introduction

Slipped Capital Femoral Epiphysis (SCFE) is a serious hip condition common among the growing adolescent population. With the emergence of childhood obesity, the incidence of SCFE is increasing and now shifting to younger age groups [1]. The current standard for management is in-situ pinning for cases of mild to moderate SCFE and open surgical realignment in severe SCFE [2]. However, the skill set to perform open surgical realignment is not always available in all centres. This has led to the use of in-situ pinning for moderate and severe SCFE in some cases. Such cases are at risk of severe proximal femoral deformity and femoro-acetabular impingement (FAI) leading to early cartilage damage. The resulting deformities also lead to gross restriction of hip motion thus negatively affecting function [3].

It has been shown that even mild SCFE leads to early cartilage and chondro-labral wear due to impingement [4]. Many advocates of hip arthroscopy have used this technique to correct FAI. In cases of moderate and severe SCFE, the deformity is more extensive and various options have been described to tackle it. Arthroscopic hip osteoplasty with proximal femoral osteotomy, surgical dislocation and osteoplasty, neck osteotomy, open anterior osteoplasty, and proximal femoral osteotomy are all described techniques for correction of deformity. Hip arthroscopy alone cannot correct all deformities in healed cases of SCFE. Furthermore, hip arthroscopy can be technically challenging in cases of moderate and severe SCFE due to the extent of the deformity [5]. Obtaining access to the hip, capsulotomy, and removing the metaphyseal bump are fairly demanding tasks. On the contrary, open neck osteotomy is an invasive procedure, which allows for better correction of deformities, and therefore restoration of anatomy, in severe cases of SCFE [6]. However, in addition to being a more invasive procedure, it also carries significant risk to the blood supply of the femoral head [7]. Avascular necrosis (AVN) of the femoral head is a devastating complication and renders the preservation of a young adult hip unlikely.

We proposed to compare these two procedures in the treatment of moderate and severe SCFE. The idea is to see if arthroscopic osteoplasty could help these patients to achieve good hip function analogous to open neck osteotomy. We have assessed the clinical, radiological, and functional outcomes of these two procedures in children with moderate and severe SCFE.

Materials and methods

We retrospectively collected the data from the hospital hip database from 2006 to 2013. There were a total of 187 patients who underwent an operation for a diagnosis of SCFE. Of these, 59 children had moderate or severe SCFE and of these, 12 had undergone open neck osteotomy through surgical dislocation for healed SCFE with a moderate to severe deformity. Ten patients with moderate to severe deformity had arthroscopic osteoplasty and other intra-articular arthroscopic procedures. These 22 patients formed the study group.

The details regarding the demographics, history, operative notes, and follow-up data of the patients were collected from the hospital medical records database after institutional audit board clearance. The radiographs of the patients were reviewed and measurements were carried out using the radiology picture archival and communication system (PACS) workstation (IMPAX, Agfa Health care N.V.). The details of the postoperative visits including complications, clinical recovery, and function were collected from the outpatient follow-up letters. All patients had the chance to complete the hip outcome questionnaires before surgery and also at the follow-up. They completed the Modified Harris Hip Score (MHHS) and Non-Arthritic Hip Score (NAHS). The senior author started doing the arthroscopic osteoplasty for SCFE after he had completed more than 100 hip arthroscopic procedures for various pathologies. The patient and family were offered both the options of open and arthroscopic surgery and given a choice to decide. They were made fully aware of the risks, benefits, and limitations of each procedure, with the family as a whole involved in the decision-making. In addition, they were fully informed of the post-operative rehabilitation and recovery. They were made aware of the limitations of hip arthroscopy in comparison to the open procedure and the relative risk of complications with each procedure. The senior author offered them, in the event of an unsatisfactory outcome with an arthroscopic procedure, a second stage intertrochanteric corrective osteotomy.

Arthroscopic Osteoplasty: In the arthroscopy group, most patients were initially treated with in-situ pinning for moderate and severe SCFE in different centers before referral to our department. They subsequently underwent arthroscopic osteoplasty in our centre under the senior author. All of them had closed physes.

Procedure

Hip arthroscopy is performed supine on a traction table after hip distraction with standard anterolateral and mid anterior portals. The senior author starts in the central compartment performing capsulotomy to connect the portals, labral-side procedures like labral repair/debridement, rim trim, cartilage stabilization, and micro-fracture before addressing the cam impingement. The head/neck junction is marked with burr and osteoplasty is performed with 5.5 mm burr. Initial osteoplasty is done with the hip in a neutral position and then in internal and external rotations. The traction is released once the central compartment is fully addressed. The peripheral compartment is further exposed by opening the capsule with a radiofrequency probe. The hip is then flexed to 30° and 60° and osteoplasty continued in both external and internal rotations. Later in 10° of extension, the posterosuperior corner is reached to anterior edges to complete the osteoplasty. The

Table 1 Results—arthroscopic osteoplasty mean and SD ($N = 10$)

	Pre-operative (mean and SD)	Post-operative (mean and SD)	P value
AP slip angle	11.6° ± 10.9	9.22° ± 10.5	0.1
Lateral slip angle	52.5° ± 9.6	44.88° ± 7.6	0.001
Oblique plane deformity	55° ± 8.9	47.1° ± 7	0.001
Alpha angle	90.7° ± 20	61.8° ± 20.9	0.0001
Anterior offset	− 0.06 mm ± 0.13	0.08 mm ± 0.15	0.001
MHHS	52.73 ± 23.1	75.5 ± 15.8	0.0005
NAHS	50.85 ± 19.2	67.12 ± 25.4	0.003

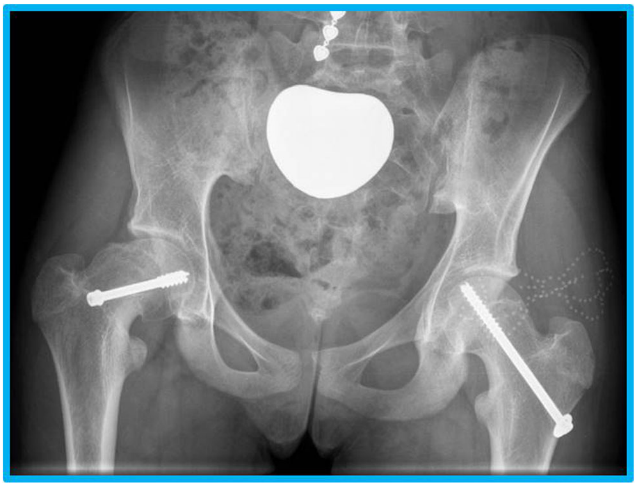

Fig. 1 AP radiography of chronic severe SCFE in a 12-year-old girl

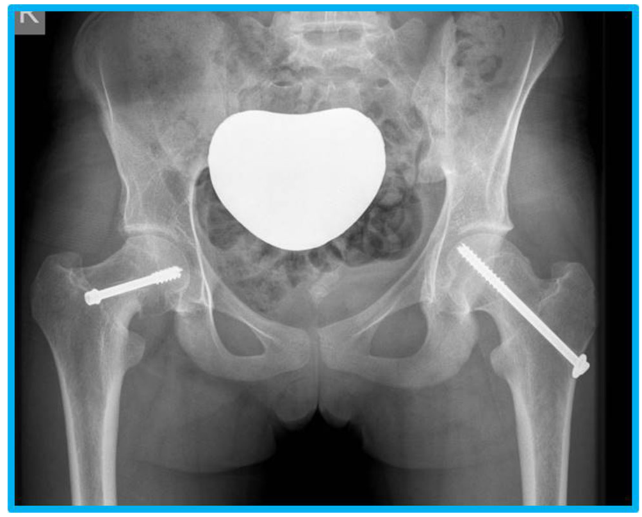

Fig. 3 Follow-up radiographs showing the correction in AP radiographs at 4 years

whole resection is checked frequently under fluoroscopy throughout the procedure. Very rarely the author switches or makes new portals (none in this series).

Pre and post-operative corrections were assessed with the help of the alpha angle, slip angle, antero-posterior (AP) offset and severity of the slip in AP, and lateral and oblique planes [8]. The range of motion of the hip was also recorded before and after the surgery. Clinical signs of impingement and pain were evaluated in the follow-up visits.

Open neck osteotomy: In the open osteotomy cohort, there were patients with and without prior pinning. All patients wanted full functional recovery to return to sports at a level they performed at prior to the slip. They were informed of the risk of AVN and chose to go ahead with the open procedure. These patients underwent open surgical dislocation via the Ganz approach and had an extended retinacular flap dissection after trochanteric flip osteotomy [7]. The neck deformity was corrected by osteotomy at the center of rotation of angulation (CORA), with realignment and fixation. The details of the correction including the same radiological parameters as described for the arthroscopic cohort were assessed for this patient group. All operations were performed by the senior author himself using the same technique in both cohorts thereby eliminating the variability in surgical technique.

All the results were collected and tabulated in Microsoft Excel 2010. The groups were compared for the clinical, radiological, and functional outcomes as described. The pre and post-operative outcome measurements for both the arthroscopy and neck osteotomy groups were computed as mean and standard deviation. The pre and post-operative outcomes measured as slip angles in the antero-posterior (AP), lateral and oblique planes, alpha angle, and head neck offset were compared for statistical association and significance using the Wilcoxon

Fig. 2 Lateral radiographs of the same patient showing the severity of the slip and deformity

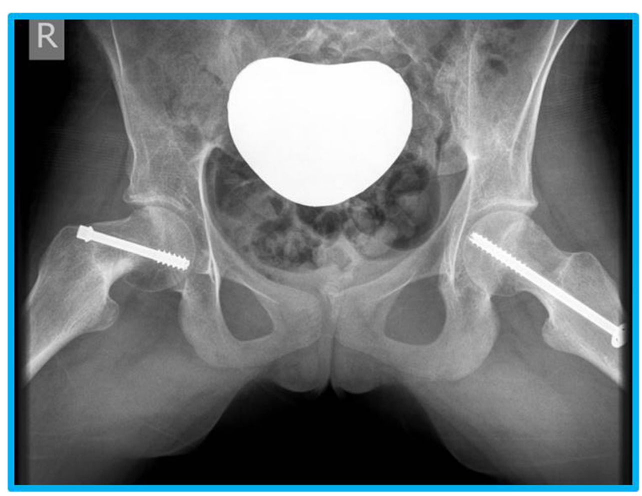

Fig. 4 4 years follow-up lateral radiograph

Table 2 Results—neck osteotomy ($N = 12$)

	Preoperative	Postoperative	*P* value
AP slip angle	34.1° (3.9°–51.6°)	10.8° (1°–17.9°)	0.009
Lateral slip angle	51.4° (32.6°–77°)	13.5° (1°–28.5°)	< 0.00001
Oblique plane deformity	69.1° (58.6°–88.9°)	16.7° (1°–28.6°)	0.001
Alpha angle	90.7° (65°–131°)	34.6° (23.2°–45.6°)	0.0001
Anterior offset	− 6.5 mm (− 3 to − 11 mm)	5 mm (2–13 mm)	0.001
MHHS	23 (0–34.1)	90 (86.2–99)	0.0005
NAHS	34.8 (0–51.25)	92.1 (81.25–100)	< 0.00001

signed rank test. Further, the outcomes between the arthroscopy and neck osteotomy groups were compared using the Mann-Whitney *U* test. A *P* value of < 0.05 was considered statistically significant.

Results

Arthroscopy cohort

There were six girls and four boys in this group of ten. The mean age at surgery was 15.8 years (range 13–19 years). The mean follow-up was 46.1 months (range 33–66 months). All except two patients had prior in-situ pinning of the slip. The mean interval between pinning and osteoplasty was 36.2 months (range 13–79 months).

The mean pre-operative slip angle in the antero-posterior (AP) plane was 11.6° (range 0.6° to 36.5°), lateral slip angle 52.5° (43.2°–76.3°), and oblique plane slip angle 55° (47.7°–63.2°). This demonstrates that almost all of them were severe slips in the oblique plane. Three patients had an oblique plane slip angle of 47°, therefore qualifying as a moderate slip. The mean pre-operative alpha angle was 90.7° (65°–131°) and pre-operative head neck offset anteriorly was - 0.06 mm (− 3 mm to 0 mm). The mean pre-operative MHHS was 52.7 (28.7–89.1) and NAHS was 50.8 (12.5–74.5).

The follow-up data showed that the mean post-operative AP slip angle was 9.2° (0.3°–28.8°), lateral slip angle was 44.8° (36.5°–64.2°), and oblique plane slip angle was 47.1° (40.2°–53.5°). The mean post-operative MHHS was 75.5 (58.75–96.8) and mean NAHS was 67.12 (18.75–100). The mean post-operative head neck offset was 0 mm (0 mm–2 mm). The mean post-operative alpha angle was 61.88° (52.1°–123°). The observed differences were statistically significant. One patient had inadequate correction due to the

Fig. 5 AP radiograph of severe healed SCFE in a 13-year-old boy. The pre-operative MHHS & NAHS were 15 and 21

Fig. 6 Radiograph of the same patient showing the deformity. Hip flexion was 45°, abduction 30°, adduction 10°, and fixed external rotation 45° with further external rotation of –60°

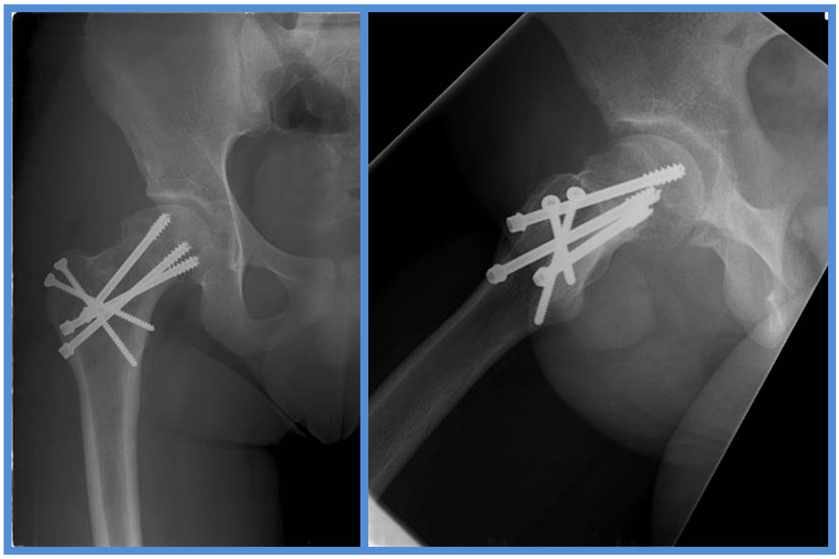

Fig. 7 Post-operative X-ray after open neck osteotomy fixed with two cannulated cancellous screws 6.5 mm and trochanteric osteotomy fixed with 4.5 mm cortical screws

severity of the deformity and another had progressed to arthritis awaiting hip replacement at the latest follow-up (Table 1).

The same two patients had persistent fixed external rotation deformity after the surgery. One was due to severity of the deformity meaning complete resection could not be performed due to technical difficulty. In the second patient, hip arthritis advanced despite arthroscopic debridement. The very severe deformity precluded the complete visualization of the superior part of the bump in the head using arthroscopy. He had improvement in flexion but not in abduction or rotation. Intra-operative findings showed a direct relationship between the duration of time from initial slip to osteoplasty. The longer the duration the worse the articular surface damage. Most patients had cartilage damage from the 11 o'clock to 3 o'clock position with an average defect of 3cm^2. As shown in Tables 5 and 4, patients had labrum debridement to a stable base as it was

Fig. 8 Follow-up AP radiographs showing the correction at 8 years follow-up. MHHS/NAHS at follow-up were 91 and 90

Fig. 9 Follow-up lateral radiographs of the same patient at 8 years. Range of motion flexion 140°, abduction 40°, and adduction 30°, internal rotation of 20°

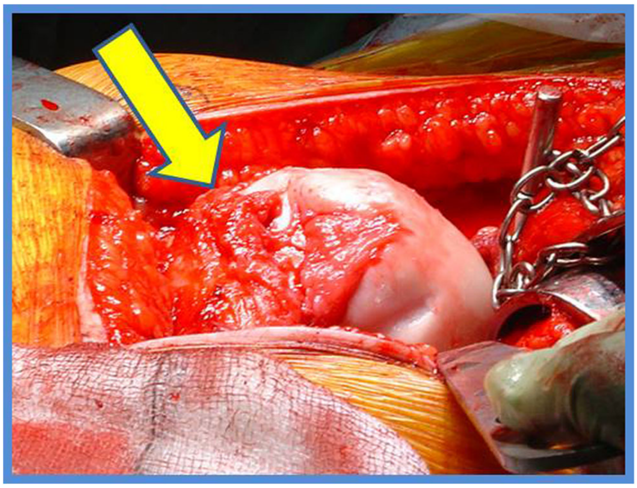

Fig. 10 Intra-operative picture of the same patient showing the callus and healing tissue (yellow arrow) in case of chronic slip which makes the dissection of retinacular flap challenging

beyond repair. Figures 1, 2, 3, and 4 show the pre and post arthroscopic osteoplasty radiographs in a child with severe SCFE.

Neck osteotomy cohort

There were six boys and six girls in the open neck osteotomy group. The mean age at surgery was 14.6 years (11–20 years). The mean duration of follow-up was 49 months (36–60 months). Out of the 12, eight patients had prior in-situ pinning. The mean interval between pinning and neck osteotomy was 14.6 months (11–24 months).

The severity of the deformity as assessed by slip angle showed that the mean pre-operative slip angle in the AP plane was 34.1° (3.9°–51.6°), in the lateral plane was 51.4° (32.6°–77°), and in the oblique plane was 69.1° (58.6°–88.9°). All patients had a severe slip in the oblique plane. The mean pre-operative alpha angle was 90.7° (65°–131°) and the mean anterior head neck offset was − 6.5 mm (− 3 to − 11 mm). The mean pre-operative MHHS was 23 (0–34.1) and NAHS 34.8 (0–51.25).

The follow-up data showed the following parameters. The mean post-operative AP slip angle was 10.8° (1°–17.9°) and lateral slip angle was 13.5° (1°–28.5°). The mean post-operative slip angle in the oblique plane was 16.7° (1°–28.6°). The mean post-operative alpha angle was 34.6° (23.2–45.6). The mean anterior offset at follow-up was 5 mm (2–13 mm). The mean post-operative MHHS and NAHS were 90 (86.2–99) and 92.1 (81.25–100), respectively. One patient was excluded from the analysis due to a coxa-vara deformity following osteotomy. This was a complicated case of fracture to the neck of femur where the pinning entry point was located. The patient had varus collapse after surgery leading to a Trendelenburg gait and measurement of angles were spurious due to the deformity. Another complication was non-union at the site of neck osteotomy in one case. This patient required a valgus subtrochanteric osteotomy to aid union. None of the patients had pain or impingement as assessed during the follow-up period. They were able to return to the pre-operative activity level as desired. In the neck osteotomy group, the post-operative corrections were significantly better (Table 2). Figures 5, 6, 7, 8, 9, and 10 show the pre-operative and follow-up radiographs of a child with severe SCFE and the intra-operative appearance of a chronic severe slip.

Comparing the two groups showed that the open neck osteotomy had significantly better results (Table 3). The range of motion data and intra articular procedures performed in both groups are tabulated in Tables 4 and 5, respectively.

Discussion

The observations from our study show that the patients in both groups had severe deformity due to SCFE. The results show that the amount of deformity correction achieved was well-meaning in the neck osteotomy group. In the arthroscopic osteoplasty group, those with severe deformities had persistent external rotation deformity after surgery. The follow-up range of motion data also reflects the functional gain achieved

Table 3 Results—comparison of outcomes between the groups

	Neck osteotomy (*N* = 12)	Arthroscopic osteoplasty (*N* = 10)	*P* value
AP slip angle	10.8° (1°–17.9°)	9.2° (0.3°- 28.8°)	0.0003
Lateral slip angle	13.5° (1°–28.5°)	44.8° (36.5°–64.2°)	0.00001
Oblique plane deformity	16.7° (1°–28.6°)	47.1°(40.2°–53.5°)	0.0003
Alpha angle	34.6° (23.2°–45.6°)	61.88° (52.1°–123°)	0.0003
Anterior offset	5 mm (2–13 mm)	0 mm (0 mm–2 mm)	0.0003
MHHS	90 (86.2–99)	75.5 (58.75–96.8)	0.003
NAHS	92.1 (81.25–100)	67.12 (18.75–100)	0.002
Internal rotation	50° (30°–70°)	20° (0–20°)	0.0002

Table 4 Mean range of motion data

Group	Flexion		Abduction		Adduction		Internal rotation		External rotation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Neck osteotomy	80°	120°	30°	45°	20°	30°	0°	50°	50°	50°
Arthroscopic osteoplasty	75°	97°	20°	35°	20°	30°	0°	20°	45°	50°

with the open neck osteotomy, which fared far better than the arthroscopic group.

Arthroscopic osteoplasty, however, did achieve good correction of the head-neck offset and alpha angle. This was reflected in the improvement of the functional scores post-operatively obtained during follow-up. Unfortunately, many patients still had pain with high-demand activities due to the residual deformity; this is not the case in the open osteotomy group. Even though the radiographic correction achieved in the arthroscopy group was not as good as the open osteotomy group, the functional outcome scores in arthroscopic group did show that all patients benefited from the procedure. Patients were satisfied with the ability to walk without a limp and to sit easily without external rotatory deformity.

The main limitation of the arthroscopic procedure is the inability to correct retroversion deformity and the difficulty in reaching the superior part of the bump with a scope in severe SCFE cases. If we subgroup the arthroscopic osteoplasty cohort into moderate and severe then we can see that the moderate cases had results comparable with those in the neck osteotomy group. In addition, we found that longer the time period between the slip and osteoplasty procedure, the harder it was to delay the onset of arthritis; impingement caused by the deformity advanced cartilage wear leading to early onset arthritis. This has been published by the senior author in a previous study [9].

Given the complexity of the deformity in SCFE, a frank discussion with the patients and families to identify their expectations and functional needs is vital to aid in decision-making as to which is the best option of treatment for them. In some cases, the option of subtrochanteric corrective osteotomy combined with osteoplasty can be considered if the patient is not happy to accept the risk of AVN associated with open procedures. The literature has time and again shown that for complex deformity post SCFE, a combination of intra-articular procedures and subtrochanteric osteotomy may need to be considered to achieve greater functional outcomes [10]. The senior author had considered this combined treatment; however, to his surprise, at 1-year follow-up, all patients who underwent arthroscopic osteoplasty were satisfied with the outcome with none of them wanting a further procedure. They were able to sit comfortably in the neutral position though they lacked internal rotation.

A systematic review by Boster et al. has shown that arthroscopic osteoplasty allows faster recovery with equally good results when compared to open neck osteoplasty; however, this study did not include SCFE cases [11]. Mardones et al. have however shown in their cadaveric study that the precision of osteoplasty is reduced when an arthroscopic technique is used [12]. The cohort of patients who resorted to the arthroscopic osteoplasty in our study were low-demand patients with little interest in sports. Obligatory external rotation deformity was corrected in all except one case (the patient didn't opt for second stage subtrochnateric osteotomy)) in the arthroscopy group. The significant improvement in the functional scores obtained post-operatively in this group supports this.

This study is not without limitations. It is a retrospective study with the use of historic data. A small number of patients in each group and short term follow-up do affect the information we could interpret. Nevertheless, the message that the minimally invasive intervention of arthroscopic osteoplasty can give favourable outcomes in selected patients with severe slipped capital femoral epiphysis has been conveyed. This is the case in those with low-functional demands.

Table 5 Intra articular procedures

	Arthroscopic osteoplasty
Labral debridement	4
Rim trim	5
Synovectomy	1
Labral stabilization	1
Micro-fracture	4
	Open osteotomy
Partial labral tear (debridement done)	1
Partial labral tear (repair done)	1

Conclusions

Delay in correcting the impingement affected the final outcome in both groups. The choice of procedure is multifactorial. Patient related factors, in particular their expectations, need to be taken into consideration. A frank discussion of the risks vs. benefits of both procedures is required. Arthroscopic osteoplasty achieved good functional scores at midterm follow-up in this study in low-demand patients.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Institutional audit and ethical board had approved this study.

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