REVIEW ARTICLE

Arthroscopy-Assisted Reduction and Fixation of Femoral Head and Acetabulum Fractures: A Systematic Review of the Literature

Mehmet Salih Söylemez, MD[1], Bahattin Kemah, MD[1], Oguz Poyanli, MD[2]

[1]Umraniye Training and Research Hospital, Department of Orthopaedics and Traumatology and [2]Istanbul Medeniyet University, Faculty of Medicine, Göztepe Training and Research Hospital, Department of Orthopaedics and Traumatology, Istanbul, Turkey

Abstract

Objective: To perform a systematic review to determine the current arthroscopic techniques of the fixation of femoral head and acetabulum fractures and assess the radiological and functional outcomes reported in literature written in English.

Methods: This review was performed by searching PubMed, Cochrane Library, Scopus, and Web of Science without a filter for time limitation in line with Preferred Reporting Items for Systematic Reviews Protocols (PRISMA-P) guidelines. Two authors took part in screening and evaluating the literature between December 2020 and January 2021. The terms acetabulum fracture, reduction, fixation, femur head fracture, fracture dislocation of the hip, hip trauma and arthroscopy or arthroscopic, and their combinations were used to search four database engines in the titles and abstracts of the reported papers. Only papers with English titles and abstracts were included. The assessment of the data related to descriptions of the techniques, indications for fracture fixation using arthroscopy, and patient-related outcomes.

Results: Perfect agreement was detected between the two reviewers during all steps of the review process ($\kappa = 0.81$–1.00). Although a meta-analysis was planned to be carried out, no randomized controlled study comparing either the radiological or functional results of different surgical techniques was detected in the literature. Nineteen studies were included in the study. Of these, 15 were retrospective case reports and four were case series. Twenty-seven patients were operated on for acetabulum fractures (18 male/nine female). The mean age was 28.3 years (range, 15–53 years). High-energy traumas including motor vehicle accidents were the most common reason (81%). The duration of follow-up was a mean of 32 months (range, 12–68 months). Sixteen patients were operated on for femur fractures (12 male/three female). The mean age was 30.1 years (range, 17–50 years). Motor vehicle accident was the most common trauma (70%). Duration of follow-up had a mean of 18 months (range, 4–60 months). Patient-related outcomes were excellent for reported cases in both groups despite the fact that an objective scoring system was not used for most of the cases. Moreover, there was no consensus on surgical indications or the techniques.

Conclusions: The techniques of arthroscopic-assisted fixation of acetabulum and femoral head fracture are so heterogeneous that conclusions cannot be made at this time, but there is potential for this method of treatment to become more popular as the devices used in the procedure develop and as exposure to and experience with hip arthroscopy improves. Further descriptions of reduction and fixation techniques and analysis of outcomes of RCTs are needed.

Key words: Acetabulum fracture; Arthroscopy; Femur head fracture; Fixation; Reduction

Address for correspondence Mehmet Salih Söylemez, Yaprak street, Acıbadem district, No 32, D:12, Uskudar/Istanbul, Postal code: 34660, Turkey Tel: +05377743669; Email: slhsylmz@gmail.com

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Introduction

Traumatic acetabulum and femoral head fractures are traditionally operated on with an open approach. While open reduction and internal fixation have been shown to be effective, there is associated morbidity with this approach, including heterotopic ossification, excessive soft tissue dissection, and improper assessment of the articular surface[1,2]. Traditional open reduction and internal fixation (ORIF) techniques remain the gold standard of management for definitive treatment of these fractures. As these are not frequent lesions, recommendations for treatment and surgical techniques must be taught. Anatomic reduction of the articular surface is the primary goal and adequate stabilization is the secondary goal. The intervening surgeon must be experienced in hip surgery to decide if it is possible to achieve these goals through arthroscopic guidance and with a percutaneous procedure[3]. Moreover, there are difficulties in understanding fracture anatomy of hip joint despite an open approach and concerns about the amount of radiation exposure compared to percutaneous procedures. Because of its "ball and socket" configuration, the hip joint is a difficult joint to treat and evaluate for potential intra-articular pathologies with hip arthroscopy.

After its first description in cadaveric studies during the 1930s, hip arthroscopy has undergone considerable advancement[4,5]. Because the techniques and indications have become better defined and instrumentation has improved, its utility has advanced in various conditions[6]. Due to its minimally invasive nature, arthroscopy has been used in different hip disorders like femoroacetabular impingement (FAI), extraction of loose bodies and foreign bodies, and debridment or treatment of labral tears[7]. However, hip arthroscopy has a long learning curve and several technical demands. The operating surgeon must have a comprehensive understanding of both the open treatment and arthroscopic treatment of hip conditions or work closely with a surgeon with a mastery of open hip approaches to carry out appropriate preoperative planning and successfully convert to open approaches in situations of arthroscopic failure.[8]

In the setting of hip trauma, arthroscopy has been used mostly in the extraction of loose bodies and the debridement of injured labrum and ligamentum teres resulting from fragmentation of the posterior wall of the acetabulum or femoral head, after reduction of hip dislocation[9]. Arthroscopy-assisted surgery of acetabulum and femur fractures have been stated to be indicated only in a restricted group of patients with minimal displacement. Because of this, patients sustaining acute displaced acetabular fractures possess an increased risk of fluid extravasation to the abdominal compartment. Using high-pressure pumps, communited medial cortex, and distorted capsular continuity have been reported to be the main reason in these cases[10]. Extraction of loose bodies arthroscopically has been reported to be successful in 93.8% of patients with prosperious functional results despite rarely reported, potentially fatal complications like intraabdominal compartment syndrome and pulmonary embolism[7,10–12].

Arthroscopy-assisted fracture fixation (AAFF) of acetabular and femoral head fractures is a relatively new method of treating these injuries and has been reported to be effective[12]. The visualization afforded by hip arthroscopy for these fractures is similar to that employed in the reduction of tibial plateau fractures. If these fractures are planned to be operated on *via* arthroscopy, several important technical points must be kept in mind. The fracture must be amenable to, and not be further displaced by, the necessary traction. The visualization in the presence of hemarthrosis may be difficult and the insufficiency of the bony architecture to contain the arthroscopic fluid must be recognized. In addition, the energy and mechanism that often accompany these types of fractures may result in a polytraumatized patient, and the associated injuries may preclude the additional surgical time and positioning required for hip arthroscopy[8]. The use of the arthroscopy-assisted fracture fixation in the treatment of acetabular and femoral head fractures has increased in the last decade. This applies not only to hip fractures but also to all fractures with intra-articular extension. Although much literature is easily accessible about arthroscopy-assisted fracture fixation of intra-articular knee and shoulder fractures, the same situation is not valid for hip fractures. This technique has the potential to become more popular as the devices used in the procedure develop, and as exposure to and experience with hip arthroscopy improves. But the literature and outcomes of arthroscopic-assisted fixation of these fractures are very limited and currently there are no systematic reviews of this issue.

From this point of view, we raised the following questions: (i) Are any new surgical techniques and/or technologies employed to ease the application of arthroscopy for fixation of femoral head and acetabulum fractures? (ii) Is it necessary to try to fix the femoral head and/or acetabulum fractures using arthroscopic techniques? (iii) Does it decrease the complication rates? and (iv) Are patient-related outcomes superior to those of open surgical techniques? We aimed to find answers to these questions, review the current literature, and provide brief but thorough more recent data on techniques, indications, complications, and patient-related outcomes on this issue.

Methods

Search Strategy

This review was performed by searching PubMed, Cochrane Library, Scopus, and Web of Science in line with Preferred Reporting Items for Systematic Reviews Protocols (PRISMA-P) guidelines[13]. There was not an *a priori* defined start publication date and all relevant studies published before January 22, 2021, were included. The terms acetabulum fracture, reduction, fixation, femur head fracture, fracture dislocation of the hip, hip trauma and arthroscopy or arthroscopic, and their combinations were used to search four database engines in the titles and abstracts of the reported papers. Only papers with English titles and abstracts were included. Search examples included Arthroscopy AND (acetabulum fracture OR femur head fracture OR fracture dislocation of the hip OR hip trauma); (Arthroscopic OR Arthroscopy) AND (acetabulum fracture OR femur head fracture OR fracture dislocation of the hip OR hip trauma); and Arthroscopic treatment of traumatic hip dislocation and Arthroscopic reduction and internal fixation of acetabular fractures.

Trials were planned to be included in line with PICOS (population, intervention, comparator, outcome, study design) criteria: (i) Population: patients with acetabulum and/or femur fracture; (ii) Intervention: arthroscopy-assisted fracture fixation; (iii) Comparator: open reduction closed fixation; (iv) Outcomes: the primary outcomes included the following: development of osteoarthritis, range of movement (ROM), Harris hip scores (HHS), visual analog scale (VAS) scores, pain, limping, and reported any other clinical survey criteria were assessed and presented; (v) Study design: RCT.

Exclusion criteria were as follows: (i) articles reporting patient-related outcomes after arthroscopic intervention for foreign body excision; (ii) labrum debridement or repair; and (iii) ligamentum teres debridment using hip arthroscopy, or arthroscopy used for diagnostic purposes only.

Study Screening

Two reviewers with comparable medical experience in orthopaedic surgery (both are assistant professor for 6 years) independently screened the titles in duplicate for inclusion. The selected papers' abstracts had undergone a second evaluation for inclusion. A meeting was held after the first two steps to exclude the duplicated data. In the title and abstract screening step, if one reviewer insisted on a paper, this study was included and its full content was evaluated.

After the first two steps, the selected full articles were coded as: arthroscopy for acetabulum fractures; arthroscopy for femoral head fractures; arthroscopy for hip fracture dislocation; arthroscopy for foreign body and bullet removal; arthroscopy for miscellaneous traumatic hip conditions; and reviews of arthroscopy after hip trauma. Review article references were evaluated for a manual search of the literature but were not included in the final evaluation. Data were abstracted and organized in spreadsheets (Microsoft Excel 2016).

Both authors embedded two different spreadsheets in a meeting after this step as well. Any conflict was resolved by assessing the full article, and the article was either included or excluded with consensus under the peer of the senior author.

Data Extraction

As the last step, full-article assessment of the selected papers was performed. Irrelevant papers were excluded. The remaining papers were coded as arthroscopy for acetabulum fracture fixation; arthroscopy for femoral head fractures fixation; and arthroscopy for fixation of both bone injuries. A standardized form was used to extract data from the included studies for assessment of study quality and evidence synthesis. Again, two review authors extracted the data independently. Any conflict at this step was resolved with a consensus meeting. Tables were created to summarize the extracted data, and missing data were indicated in the tables.

Although a meta-analysis was planned to be carried out, no randomized controlled studies comparing either the radiological or functional results of different surgical techniques were detected in the literature. Thus, extracted information for assesment included the following.

Study Settings

Study settings were evaluated to define the trends in frequency of AAFF applications, study concepts, and the quality of the studies over time. Number of studies and individuals, study designs, and publication dates of studies were assessed and presented.

Study Population

Demographic features and trauma patterns of individuals were evaluated to define the target population for AAFF. Age, gender, side, trauma pattern, time from trauma to surgery, associated injuries, and duration of interventions were assessed and results were presented as numbers, percentages, and mean values from pooled data.

Indication for Arthroscopy-Assisted Fracture Fixation

Reported indications for AAFF of femur and acetabulum fractures were evaluated to define exact indications for AAFF. The extend of femoral head fractures were classified using Pipkin classification system[1].

Pipkin classifies femoral head fractures in four types: type 1: fracture inferior to the fovea capitis; type 2: Fracture separates the fovea capitis from femoral head and extends above the fovea capitis; type 3: femoral neck fracture with Pipkin type 1 or 2 fracture; type 4: Pipkin type 1 or 2 with acetabular fracture.

Acetabulum is connected to the pelvic cavity and acetabular fractures operated with AAFF, with or without extension to the pelvic cavity, were included in the study and classified if possible. Fractures of acetubulum were classified using Thompson and Epstein classification or Judet and Letournel classification[2,3]. Thompson and Epstein classification system defines the fracture dislocation of the hip in five categories: type 1: dislocation with or without a minor fracture; type 2: dislocation with a large single fracture of the posterior acetabular rim; type 3: dislocation with communition of the acetabular ring; type 4: dislocation with a fracture of the acetabular floor; type 5: dislocation with a fracture of the femoral head.

Judet and Letournel system classifies acetabular fractures as simple and complex fractures. Anatomical structures that are key to the classification are the anterior and posterior walls of the acetabulum and the anterior and posterior columns of the innominate bones. The morphology of fracture patterns is described with extent of fracture lines among these anatomic structures. There are 10 major fracture patterns, which consist of five simple patterns and five complex patterns. Type of fractures classified using a classification system or amount of reported displacement were assessed and presented.

Technique

Techniques were analyzed to define the possible techniques that may ease the application of AAFF for hip fractures, enable further development of techniques, and may prevent further complications. Reported technical details including preoperative preparation, position of the patient, method for using irrigation solution, type of scope used for arthroscopy, portal placement, additional intervention for associated injuries, features of fixation material, and duration of follow-up were assessed and presented.

Complications

Complications were evaluated to determine the efficacy of AAFF and analyze possible reasons of complications. Any reported complication including failure of fixation, nonunion, malunion, infection, compartment syndrome, neurovascular damage, insufficient reduction, and other related data were assessed and presented.

Patient-Related Outcomes

Patient-related outcomes were analyzed to determine the clinical efficacy of AAFF. Development of osteoarthritis, range of movement (ROM), Harris hip scores (HHS), visual analog scale (VAS) scores, pain, limping, and any other clinical survey criteria were assessed and presented[5].

HHS assess the pain level, functionality (walking and daily activities), deformity, and range of motion using a scoring system. The survey scores range from 0 to 100 with higher scores representing less dysfunction and better outcomes. The significance of results are interpreted as follows; <70 = poor result; 70–80 = fair, 80–90 = good, and 90–100 = excellent.

VAS is a survey to evaluate the level of acute or chronic pain. Patients are asked to define the pain score from 0 to 10. A score of 0 is defined as no pain and 10 is defined as the worst pain ever that the patient has experienced.

Quality Assessment and Statistical Analyses

The quality of the reviewed work was indicated using the "Level of evidence" method from Level I to Level V[14]. As no RCTs were detected in the current literature, formal statistical analyses were not possible. Descriptive statistics for the included studies were presented. For all stages of the abstract and full-text screening, a k (Cohen's kappa) was calculated to assess inter-rater agreement including the relevance of the articles (relevant or not), gender, side, trauma pattern, existence of associated injuries, position during surgery, type of scope, existance of additional interventions for associated injuries, types of fixation material, existence of complications, and achaievement of union. A k value of 0.81–1.00 indicated almost perfect agreement. A k value of 0.61–0.80 indicated substantial agreement; a k value of 0.21–0.60 indicated moderate agreement; and a k value of 0.20 indicated lower or slight agreement. SPSS software (ver. 26.0; IBM Corp., Armonk, NY, USA) was used for inter-rater agreement analyses.

Results

Systematic Search

After primary searching, 1618 titles were noted in the four databases. After the removal of duplicate data, 723 articles were assessed for their titles. Of these articles, 520 reports were extracted from PubMed. Of these, 44 were selected for further review after title evaluation. Only one report was detected using the Cochrane library, and this was not relevant to our research. Eight articles were detected in Scopus, and of these seven were duplicates of the PubMed search. One was selected for further review after title evaluation. In total, 234 articles were detected in Web of Science, and of these 33 were duplicates of the PubMed search. Eleven were selected for further review after title evaluation.

After title research, 56 articles were selected for abstract evaluation. Twenty-three of the selected articles that did not meet the inclusion criteria were excluded from the study. Of these, five were review studies. The reference lists of these five review studies that did not meet the inclusion criteria were also reviewed. Screening of the reference sections of these five studies yielded three additional articles. These three articles were added to the list for full article assessment after abstract evaluation. The remaining 28 records were evaluated for full-text assessment. Of these, eight were found to not be eligible after full-text assessment. One more study was included, detected from the reference lists of the records that had undergone full-text assessment (Figure 1). Perfect agreement was detected between the two reviewers during all steps of the review process ($\kappa = 0.81–1.00$).

Nineteen studies were included in the study. Of these, four were case series and the remaining were case reports. Eleven were AAFF of the acetabulum, seven were AAFF of femoral head fracture, and in one case series there was one acetabulum and one femoral head fracture case treated using AAFF. There were no studies using AAFF for both acetabulum and femur fracture for the same case.

Quality Assessment

Our study is a Level IV study, as all included studies were case series or case reports and, therefore, had a level of evidence of Level IV[14]. Any study comparing patient-related outcomes between open and arthroscopic fracture fixation for acetabulum or femoral head fractures were not identified. A formal analysis of the dataset could not be carried out, as obtaining a homogenous dataset at all levels was impossible.

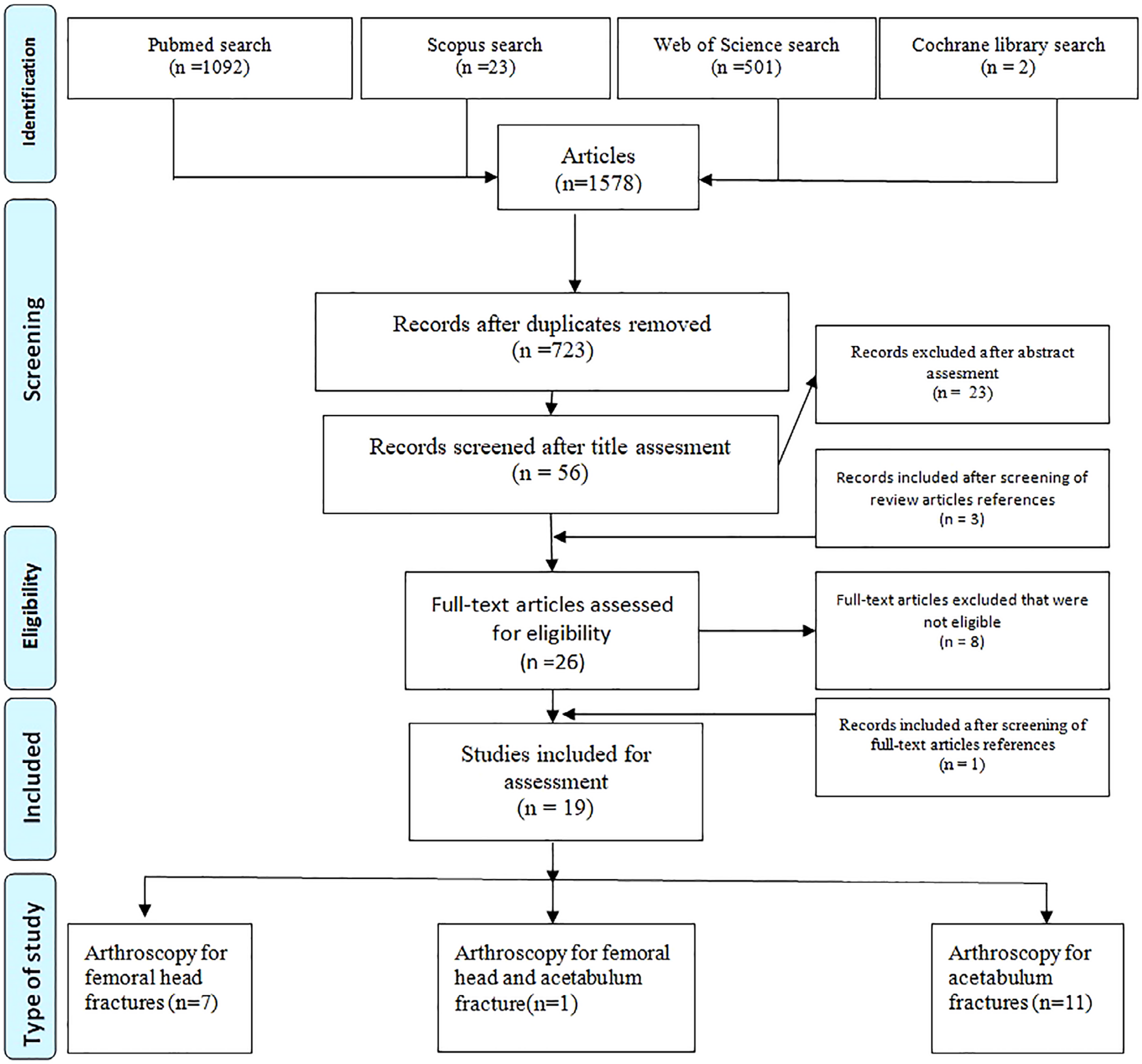

FIGURE 1 Study selection process (PRISMA 2009 diagram[15])

Arthroscopy-Assisted Acetabulum Fracture Reduction and Fixation

Study Setting

Twelve articles were included[16–27]. Of the evaluated articles, 10 were retrospective case reports (Level V) and two were case series studies (Level IV). Twenty-seven patients were operated on using AAFF for acetabulum fracture. Of these, 13 were from one study[20] and the remainder were from the other studies. Excluding one case from 2003[21] and one case from 2009[16], all cases were operated on in the last decade.

Study Population

Eighteen patients were male and nine were female. The mean age was 28.3 (15–53) years. There was bilateral involvement in one case[17]. For 13 patients, the right hip was operated on, while for 12 patients, the left hip was operated on. In five cases, a stress fracture of the acetabular labrum was the etiology[16–19]. High-energy traumas including motor vehicle accidents, car accidents, and falls from a height or during exercises were the most common reasons (81%). Time to surgery was reported to be a mean of 4.8 (3–8) days in one case series including 13 patients, and 7 days in one case report[20,22]. Duration of surgery was reported for only one case and was 120 min[25]. The duration of follow-up was a mean of 32 (12–68) months (Table 1).

Indications for Arthroscopy-Assisted Fracture Fixation

No studies reported the indication for surgery using a standard classification system. However, the most common

TABLE 1 Current literature related to arthroscopy-assisted acetabulum fracture fixation

Author and Year	Level of Evidence	Number of patients	Gender	Age (Years)	Side	Time to surgery (days)	Trauma	Indication for arthroscopic fixation
Zhao *et al.*[20]	Case series(IV)	13	9M, 4F	23.7 (15–36)	8L, 5R	4.8 (3–8)	High energy	Nonconcentric reduction after initial reduction of hip dislocation on X-rays. Associtaed acetabulum posterior rim fracture verified with CT.
Gürpınar *et al.*[27]	Case report (V)	1	M	49	R	*	Fall from height	Displaced posterior wall fracture
Torres-Eguía *et al.*[18]	Case report (V)	1	F	*	L	*	Stress fracture	Nonunion after acetabuar rim stress fracture causing FAI
Shakuo *et al.*[25]	Case report (V)	1	M	49	L		Snowe board	Acetabulum anterior column fracture. Percutaneous pinning assisted under direct vision of the joint with arthroscopy
Rafols *et al.*[17]	Case report (V)	1	M	20	L + R	*	Stress fracture	Nonunion after acetabuar rim stress fracture causing FAI
Stabile *et al.*[24]	Case report (V)	1	F	46	R	*	Motor vehicle accident	Nonconcentric reduction after initial reduction of hip dislocation on X-rays. Associtaed acetabulum posterior rim fracture with buckle handle labral tear verified with CT.
Kim *et al.*[23]	Case report (V)	2						
Case 1			M	49	R	*	Car accident	Displaced posterior wall fracture due to fracture dislocation
Case 2			F	20	R	*	Car accident	Displaced anterior column fracture extending to the iliac wing
Götz *et al.*[26]	Case report (V)	1	M	53	R	*	Fall from bcycle	Acetabulum anterior column fracture. Using direct vision of the joint with arthroscopy to prevent perforation of the screws into the joint during ORIF with plates and screws
Larson *et al.*[19]	Case report (V)	2						
Case 1			M	25	L	*	Stress fracture	Nonunion after acetabuar rim stress fracture causing FAI
Case 2			M	18	R	*	Stress fracture	Nonunion after acetabuar rim stress fracture causing FAI
Yang *et al.*[22]	Case report (V)	2						
Case 1			F	18	R	7	Motor vehicle accident	Transverse acetabulum fracture displaced at anterior column. Percutaneous pinning assisted under direct vision of the joint with arthroscopy
Case 2			F	15	L	*	Fall during exercise	Acetabulum anterior column fracture with dome involvement. Percutaneous pinning assisted under direct vision of the joint with arthroscopy
Epstein *et al.*[16]	Case report (V)	1	M	36	L	*	Stress fracture	Nonunion after acetabuar rim stress fracture causing FAI
Yamamato *et al.*[21]	Case series(IV)	1	M	30	R	*	Car accident	Acetabulum medial wall fracture due to central dislocation.

Abbreviations: CT, computed tomography; FAI, femoroacetabular impingement; F, female; L, left; m, male; R, right; *, have not mentioned

reason was the nonconcentric reduction after initial reduction of posterior hip dislocation on X-rays (Thompson and Epstein type III fracture) or associated acetabulum posterior rim fracture verified with CT (15 cases, 55%)[20,23,24]. Nonunion after acetabular rim stress fracture causing FAI was the reason for surgery in five cases[16–19]. Other indications for surgery were isolated anterior column fracture or anterior column fracture extending to the dome or posterior column in five cases[22,23,25,26] (for these fractures, AAFF had been used as an additional tool to obtain a direct view of the articular surface to assess the reduction and perforation of the screws into the joint), displaced posterior wall fracture in one case[27], and medial wall fracture in one case[21] (Table 1).

Technique

Operations were performed on a traction table in the supine position in 11 studies and on a routine fracture table in one study[26]. These authors using AAFF to assess the intra-articular perforation of the screws used for ORIF of anterior column fracture of the acetabulum had used a Schanz screw inserted into the collum femoris to distract the joint and manipulate the femoral head. The authors had used a single anterolateral portal to view the joint[26]. One author using the technique for percutaneous pinning of the anterior column fracture had used a traction table for the distraction while the contra-lateral limb in the lithotomy position allowed for viewing of C-arm images and arthroscopic visualization simultaneously. In nine studies, anterolateral, anterior, and posterolateral portals had been reported to be routine portals for intervention of the fracture. One author had used auxiliary portals for fixation of the posterior rim fracture with labrum injury[20]. One author used anterolateral, midanterior or ancillary, and distal anterior portals for intervention of an acetabulum stress fracture[18]. In six studies, the authors had performed a capsulotomy to enhance the vision and enable the manipulation of the fragment[16–20,27]. In one study treating posterior acetabular rim fractures, the authors had positioned the leg in 5° of adduction and 10° on internal rotation to enhance the vision and manipulate the fragment[20]. In two studies, the authors had used a K wire as a joystick to reduce the fracture under direct vision of the scope. Torres *et al.*[18] had advocated for using K wires and screw drivers for as long as possible. Rafols[17] had knotted the screw head to a security knot to prevent the screw from falling in the soft tissue. One author had performed a cam resection to prevent failure of the fixation of osseo-labral injury from a silent impingement detected on X-rays preoperatively[24].

In one study, 3.5-mm suture anchors for small fragments had been used as a kind of suture bridging technique. For larger fragments, two suture anchors of the same size had passed through the fragment and knotted over the fragment[20]. For other technical and fixation details, please see (Table S1).

Complications

Among 27 cases, only one complication was reported (3.7%). Shakuo *et al.*[25] had reported an abdominal compartment syndrome after AAFF for anterior column fracture using the percutaneous pinning technique. The authors had used a 100 mmhg pressure to decrease the bleeding and increase the vision. Percutaneous peritoneal drainage was performed and the patient had been reported to recover.

Patient-Related Outcomes

Patient-related outcomes were reported for 24 cases. The duration of follow-up was a mean of 32 (12–68) months. In 26 cases, full union had been reported. In neither of the studies was the early development of osteoarthritis reported. Hip ROM was reported for 26 cases and was within normal ranges in 24 cases. Harris hip scores (HHS) were reported for 18 cases and the range was between 90 and 100 points (excellent result). Pain and limping in daily life were not reported after at least 1 year of follow-up in 24 cases (Supplement table 1).

Arthroscopy-Assisted Femoral Head Fracture Reduction and Fixation

Study Setting

Eight articles were included[21,28–34]. Of the evaluated articles, five were retrospective case reports (Level V) and three were case series studies (Level IV). Sixteen patients were operated on using AAFF for femoral head fracture. Of these, seven were from one study[29] and the remainder were from the other studies. Excluding one case from 2003[21] and one case from 2009[34], all cases were operated on in the last decade (Table 2).

Study Population

Twelve patients were male and three were female. The mean age was 30.1 (17–50) years. For nine patients, the right hip was operated on, while for seven patients, the left hip was operated on. Motor vehicle accident was the most common trauma (12 cases, 70%). Crush while snowboarding was the trauma in two cases and car accident was the trauma in one patient. Time to surgery was reported to be a mean of 6.8 (4–14) days for five studies. The duration of surgery was reported in only one case series including seven cases and was a mean of 248 (170–320) min[29] (Supplement 2).

Indications for Arthroscopy-Assisted Fracture Fixation

Pipkin type 1 infra-foveal fracture that had occurred after posterior hip dislocation was the most common fracture type (eight cases). In eight cases, Pipkin type 2 fracture was the fracture type. Among Pipkin type 2 fractures, two had occurred after anterior hip dislocation (at the weight-bearing area)[28,33]. One was an isolated fracture (at the weight-bearing area)[34]. The remaining five cases had occurred after posterior dislocation of the hip[29]. The indication for surgical fixation was reported to be displacement more than 2.0 mm in CT images and a fragment larger than 2.0 cm for seven cases in only one study[29] (Table 2).

Technique

All of the operations were performed on a traction table in the supine position. In seven studies, the routine anterior and anterolateral portals were used for vision and working[28–34]. In six studies, an additional one or more portals were opened for fracture fixation[28,29,31–34]. For Pipkin type II fractures, one author[29] had positioned the affected limb in maximal external rotation under moderate traction and the other[33] had internally rotated and gotten the hip into 10° of adduction to obtain the direct vision of weight-bearing areas of the femoral head. For Pipkin type I fractures, in four studies fracture margins were visualized by positioning the

TABLE 2 Current literature related to arthroscopy-assisted femoral head fracture fixation

Author and year	Level of evidence	Number of patients	Gender	Age(years)	Side	Time to surgery (days)	Trauma	Indication for arthroscopic fixation (classification of the fracture)
Sobcyzk *et al.*[28]	Case report (V)	1	M	18	R	*	Snowboard	Pipkin type 2 fracture of weight bearing area (Suprafoveal) after anterior hip dislocation
Hsu *et al.*[29]	Case series(IV)	7	M	26(17–28)	4 R,3 L	4 to 7	Motor vehicle accidents	Presence of fracture fragment >2 cm in size and displacement >2 mm from the CT scan. Pipkin type 2 five and type 1 two fractures
Alfikey *et al.*[30]	Case series(IV)	1	F	28	R	7	Motor vehicle accident	Pipkin type 1 infrafoveal fracture afer hip fracture dislocaton
Kekatpure *et al.*[31]	Case report(V)	1	*	*	R	*	*	Pipkin type 1 infrafoveal fracture afer hip fracture dislocaton
Park *et al.*[32] Case 1	Case report(V)	3	F	50	L	*	Motor vehicle accident	Pipkin type 1 infrafoveal fracture afer hip fracture dislocaton
Case 2			M	34	L	*	Motor vehicle accident	Pipkin type 1 infrafoveal fracture afer hip fracture dislocaton
Case 3			M	46	L	7	Motor vehicle accident	Pipkin type 1 infrafoveal fracture afer hip fracture dislocaton
Matsuda[33]	Case report (V)	1	M	23	R	14	Snowboard	Pipkin type 2 fracture of weight bearing area (Suprafoveal) after anterior hip dislocation
Matsuda[34]	Case report (V)	1	F	19	L	7	Motor vehicle accident	Displaced Pipkin type 2 fracture of weight bearing area (Suprafoveal) fracture
Yamamato *et al.*[21]	Case report (IV)	1	M	27	R	*	Car accident	Pipkin type 1 femoral head fracture associated with type 1 acetbulum rim fracture.

Abbreviations: CT, computed tomography; F, female; L, left; M, male; R, right; *, have not mentioned.

hip at varying degrees of knee flexion and hip flexion, hip abduction, and external rotation[21,30–32]. Guide pins, switching sticks, surgical graspers, elevators, and probes have been reported to be used as joysticks or "chopsticks" for fracture manipulation and reduction[29,32,34]. Before permanent fixation, the fragment had been provisionally fixed with 2 K wires[28,32]. Another had introduced the screw with a loop of vicryl lassoed around the neck of the screw to prevent it from falling[31]. In one study, the authors had performed an acetabuloplasty to decrease the acetabular coverage due to acetabular over retroversion and to address the silent FAI, as well as to create a pathway for appropriate placement of screws into the femoral head perpendicular to the fracture line for a Pipkin type II fracture[33]. For other technical and fixation details, please see (Table S2).

Complications

Hsu *et al.*[29] had reported a postoperative temporarily sciatic nerve palsy in one patient (6.25%) with ipsilateral femoral head and shaft fracture. However, nerve functions had been regained after 3 months.

Patient-Related Outcomes

Patient-related outcomes were reported for 15 cases. Duration of follow-up was a mean of 18 (4–60) months. In 15 cases, full union had been reported. Early onset of osteoarthritis was reported for only one case that had sustained a Pipkin type 1 fracture associated with posterior acetabular rim fracture[21]. Hip ROM was reported for 14 cases and all were within normal range. HHS was reported for seven cases and was a mean of 90.8 (88–93) (excellent result)[29]. Pain and limping in daily life were not reported after at least 1 year of follow-up in any one of the cases. For seven cases, a moderate limitation in squatting was reported after a mean of 18 months of follow-ups[29]. The non-arthritic hip score was reported to be 98 for one case[32] (Table S2).

Discussion

This is the first study that systematically analyzes the previous and current literature on AAFF of hip fractures. In this study, we summarize the most recent data on indications, techniques, complications, and patient-related outcomes for AAFF for hip fractures. Also, we sought to find answers to the following questions to clarify whether performing AAFF for hip fractures is simply an academic adventure to satisfy ourselves or whether it is a useful tool when used in educated hands.

Although acetabulum and femoral head fractures are not uncommon, our search revealed that there are few studies reporting the techniques and results of AAFF of these fractures. There are several reasons for this situation. The difficult anatomy being the most challenging reason; long learning curve and several technical demands of hip arthroscopy, the complexity of particularly acetabular fractures, difficulties in fixation of the femoral heads weight-bearing area fractures by percutaneous means, potential risk of fluid extravasation to the intraabdominal compartment in fractures extending to the quadrilateral area, and reported acceptable results with ORIF may have prevented acetabulum and femoral head fractures from being treated by arthroscopic guidance in a large area.[8,10]

Are any New Surgical Techniques and/or Technologies Employed to Ease the Application of Arthroscopy for the Fixation of Femoral Head and Acetabulum Fractures?

All literature included in the study were from the last two decades and all were Level IV and V studies. Although there was an increase in AAFF for acetabulum and femoral head fracture fixation in the last 5 years, literature still lacks comprehensive usage of AAFF for these fractures. Despite the significant development of techniques, and particularly devices and fixation materials used for shoulder and knee trauma, we did not observe such a proceeding for hip fractures. The techniques that are used are still similar and we did not detect any new device or fixation material that had been described for fracture fixation after hip trauma.

Is it Necessary to Try to Fix the Femoral Head and/or Acetabulum Fractures Using Arthroscopic Techniques?

Arthroscopy-assisted surgery of acetabulum and femoral head fractures is indicated only in a restricted group of patients with minimal displacement[23]. Reported acetabulum fractures treated with arthroscopic guidance are mostly Thompson and Epstein type III comminuted fractures and, rather than reduction and fixation of the fracture, extraction of fragments or treatment of labral pathology had been performed[6,24]. In contrast with these studies, a previous study by Zhao *et al.*[20] implies that rather than the excision of even small fragments of up to 1.3 cm, fixation of these fractures yields excellent functional outcomes at short-term follow-ups. However, most papers using arthroscopic guidance for acetabular fracture fixation did not set forth a detailed arthroscopic reduction and fixation technique that can be applied with ease.

Percutaneous fixation of acetabular and pelvic ring fractures is very debatable, but there is a rising popularity in fixing these fractures with percutaneous means. Up to now, several imaging techniques and devices have been described to obtain a perfect track for percutaneous screw insertion[35,36]. Yet screw penetration to the joint remains a major problem and direct visualization *via* hip arthroscopy seems to be effective in preventing this problem. Patients sustaining acute displaced acetabular fractures possess an increased risk of fluid extravasation to the abdominal compartment. Using high-pressure pumps, communited medial cortex, and distorted capsular continuity have been reported to be the main reason in these cases[10,25]. Thus, it is advised that this technique be used in minimally displaced fractures that can be reduced by closed means.[21,22]

Also, arthroscopy-assisted fixation of the femoral head seems to be applicable only for the treatment of Pipkin type I and II fractures. Type I fractures situated at lateral weight-bearing are more prone to causing future osteoarthritis. Thus, operating type 1 fractures using AAFF will have several advantages over open reduction, as ORIF of the femoral head has a substantial risk for avascular necrosis[28–32]. Type 2 fractures at the infra-foveal area are relatively more prone to being fixated with AAFF as placing the hip in abduction, flexion, and external or internal rotation enables a relatively better visualization for the surgeon with arthroscopy[21,33,34].

With current techniques and tools, hip arthroscopy is a complementary possibility for stable fracture patterns and almost never a first-choice procedure for fractures that cannot be reduced by closed means and acetabular fractures extending to the inner cortex of the quadrangular area[3]. The only exception may be the fixation of osseo-labral fractures detached from the posterior acetabular wall after hip dislocation and isolated posterior wall fractures. These injuries are relatively stable and, if isolated, can be treated very successfully in the hands of an experienced arthroscopist. However, management of the femoral head fractures depends on their size and location. Pipkin type I and II fractures without an associated pelvic ring or acetabular column fractures can be treated successfully with a low complication rate using AAFF. Furthermore, in these selected patients, arthroscopy may enable the intervening of both acetabular and femoral pathologies in the same session by closed means[37].

Does it Decrease Complication Rates?

Up to the last two decades, safe dislocation, fragment extraction with or without fragment fixation, or labrum repair have been the mainstream treatment modalities for non-concentric reduction after hip dislocation. However, these are relatively traumatic procedures and are prone to increased risk for avascular necrosis of the femoral head[21,38,39]. Following these traditional treatment procedures for hip fracture dislocations, major complications including AVN, osteoarthritis, and heterotopic ossifications between 4% and 78% have been reported after the first 5 years of trauma[9,38,40]. Although there is not enough data to compare the complication rates after ORIF and AAFF for these fractures, the reported 4.6% complication rate after AAFF seems to be promising and following the rules of hip arthroscopy may decrease the rate of these complications.

Are Patient-Related Outcomes Superior to those of Open Surgical Techniques?

Although reported results are very limited, patient-related outcomes are very promising. All patients had achieved union and the reported HHS results were all excellent. Osteoarthritis, AVN, heterotopic ossification, or a remarkable limitation in hip ROM was not reported for any of the patients. However, it must be kept in mind that the development of osteoarthritis and avascular necrosis is also associated with the degree of trauma rather than the treatment modality. Patients treated with AAFF are mostly selected cases with less severe injuries[38].

Conclusion

Arthroscopy-assisted fracture fixation of acetabular and femoral head fractures can be carried out successfully in selected cases. Rather than its advantages of being minimally invasive, it has the advantage of allowing intraoperative direct assessment of reduction, extraction of free fragments, and debridement of the joint. Yet the operating surgeon must have mastered both hip arthroscopy and open hip surgery to prevent failure and potential fatal complications resulting from inadequate preoperative planning. The literature and outcomes of arthroscopic-assisted fixation of acetabulum and femoral head fracture are very limited, but there is potential for this method of treatment to become more popular as the devices used in the procedure develop and as exposure to and experience with hip arthroscopy improves. Further descriptions of reduction and fixation techniques and analysis of the outcomes of RCTs are needed.

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Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

Table S1 Technical notes for arthroscopy-assisted acetabulum fracture fixation

Table S2 Technical notes for arthroscopy-assisted femoral head fracture fixation

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