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Techniques and results of reconstruction of femoral head fractures: An Update☆

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ABSTRACT

A narrative review of the literature was conducted to examine the data on femoral head fractures, with a particular focus on their management, complications and clinical outcomes.

A PRISMA strategy was used. Medline and Scopus library databases were queried using pre-defined MeSH terms and Boolean operators. Quality of evidence was evaluated based on OCEBM and GRADE systems. The 50 eligible articles that met the predefined inclusion criteria reported on 1403 femoral head fractures. A detailed analysis of the surgical approaches used was performed in 38 articles with 856 fractures.

Most fractures were treated surgically (90,8 %) with preferred anatomical reconstruction in 76,7 % of all operatively treated cases. Posterior approaches were the most common (52.5 %). This was evenly split between surgical hip dislocation and the classic Kocher-Langenbeck approach. 70.5 % of surgically treated cases achieved excellent or good result according to Thompson-Epstein criteria. Highest rate of excellent results showed minimal invasive osteosynthesis and surgical hip dislocation. Major late complications were avascular necrosis (10.8 %), post-traumatic arthritis (16.2 %) and heterotopic ossification (20.8 %). Secondary THA was necessary in 6.9 %. Highest rate of major complications was joined with anterior approach (77 %), lowest rate from frequently used approaches surgical hip dislocation (37.8 %).

Conservative treatment recedes into the background. The Ganz flip osteotomy with surgical hip dislocation allows safe treatment of all types of fractures and should be considered the first choice, offering the lowest rate of complications and one of the best functional outcomes. Reconstruction of Pipkin Type III fractures should be reserved for very young patients due to high rate of major complications.

Introduction

Femoral head fractures are rare traumatic injuries usually associated with posterior hip dislocations. Treatment possibilities of these precious fractures include reconstruction of femoral head, excision of fractured fragment and total hip replacement. The growing surgical experience in the field is reflected in more publications on the subject. As typical high energy injury, most frequent is femoral head fracture in younger population and effort on preserving original hip joint is then leading strategy in decision process making when chance of femoral head survival is significant. Reduction of the fracture followed by osteosynthesis is therefore the preferred approach for the majority of fractures.

Controversy still exists about the preferred strategy for reconstruction - in particular, the approach for different types of fracture. In 2009, Giannoudis et al. analysed more than 450 femoral head fractures in the systemic review [1]. Influence of the approach and treatment strategy on functional result was analysed on 135 fractures. Almost 15 years have passed since this meta-analysis and much new information has been published in this field.

Therefore, the focus of this narrative review which included the last 20 years of published literature was: a) to analyse different surgical approaches used for the treatment of femoral head fractures; b) to report on the type and incidence of complications and c) to evaluate the functional outcomes of treatment.

☆ COMPLIANCE WITH ETHICAL STANDARDS

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Materials and method

Search strategy and criteria

A literature search was undertaken focusing on studies that have been published on the surgical management of femoral head fractures using the PRISMA guidelines [2].

Original articles were searched through Medline and Scopus databases using a list of Medical Subject Headings (MeSH) terms and Boolean operators:

„femoral head“, „fracture“, „hip dislocation“, „Pipkin fracture*“, and the appropriate MeSH terms: „femur head“ AND „fractures, bone“ AND „hip dislocation“, written in the English language from 2000 to June 2023, exclusively in human.

Study selection

Using the population intervention comparison outcomes (PICO) method [3] inclusion criteria were set as follows;

Population: adult patients above 18 years of age, having sustained femoral head fractures, with or without hip dislocation, treated exclusively with reduction and fixation of the fracture; No limitations were set on ethnicity, sex or co-morbidities. *Intervention*: open or closed reduction and internal fixation of the femoral head *Comparator*: different surgical strategies used; *Outcomes*: as primary outcome it was set fracture healing. Secondary outcomes set included: functional outcome, development of arthritis, avascular necrosis, infection, and re-operations.

To be eligible, each article must include at least 3 patients. The citation lists of the review articles and case reports were further searched to identify potentially eligible articles.

All details regarding classification, treatment, outcome, complications and duration of follow up were recorded. Two reviewers independently scrutinized the title and abstract of each retrieved article, and full text of the manuscript was obtained. The names of authors, institutions or journals were present to both reviewers. Any disagreement between the two reviewers was resolved by consensus. Exclusions criteria included subjects aged 16 years or less, case reports, biomechanical studies, cadaveric studies, literature reviews, technical notes, letters to the editor, editorials and educational course lectures.

Data collection

The retrieved data were collected into customized tables and are grouped according to the method of management, i.e. the strategies of approach and fixation, open or closed management and fracture types. The evidence reviewed in the latter group was further subdivided according to the different techniques described by the authors.

For in-depth analysis of surgical approaches were selected studies, where surgical approach was mentioned and at least one of the following outcomes was included: 1) division into Pipkin Type fractures 2)surgical strategy 3)functional result measured by T-E criteria and 4)complications. Additional analysis was performed for different groups of Pipkin fractures too.

Assessment of methodological quality

Methodological quality of the included studies was assessed and graded using the OCEBM ‘Levels of Evidence’ guidelines [4].

The overall quality of evidence in this systematic review was evaluated using the grading of recommendations, assessment, development and evaluation (GRADE) system [5]. Recommendations were classified as either high, moderate, low, or very low according to the authors’ interpretation of the true effect in the study compared to the estimated effect. This approach involved grading the evidence included based on the criteria for risk of bias, imprecision, inconsistency, indirectness and publication bias.

Statistical analysis

Numbers ver. 13.2 for MacOS (Apple Inc.) was used to collect the extracted data. Statistical analysis was performed with Excel 2019 for Mac (Microsoft corp, Redwood, Washington. Associations between qualitative variables were examined using the Chi-square or Fisher’s exact tests, as appropriate, and Odds ratio analysis was performed for comparing incidence of risk.

Results

Search results

The PRISMA flowchart is shown in Fig. 1.

The electronic search in Medline, limited to publications in English and to clinical papers dealing exclusively with humans, yielded 566 citations. The electronic search in Scopus, restricted to English language publications and to clinical papers dealing exclusively with humans, yielded 1289 citations by mapping to the preferred terminology, by searching also for synonyms and by exploding on the preferred terminology. Upon removal of duplicates between the databases, the overall articles screened were 1369. After exclusion based on title and abstract information and not retrieved reports, 120 articles remained from both groups. The next 71 articles met the exclusion criteria and were removed. One study was added from different sources. The selection criteria were finally met by a total of 50 articles, which were critically analysed to form the report of this study [6–55].

Methodological quality

OCEBM ‘Levels of Evidence’ (Appendix 1) showed the overall level of evidence of 46 included studies as "level IV". 4 studies were randomized control studies and were graded level II, moderate [13,17,21,42]. The remaining articles are retrospective observational studies or case series. In addition, an overview of the GRADE analysis assessment, which demonstrated the quality of evidence to be Low for all case series, as there were no large observational studies is presented. Quality of evidence of four included RCTs was rated as moderate.

Demographics and classification

The 50 articles reported on 1403 fractures of the femoral head. All articles used Pipkin’s classification system, majority of them as main classification system, in some articles was Pipkin’s classification used as second classification or was “modified” [10,12,52], but data on the division into the main Pipkin types can be obtained. There were 398 Type I (28,4 %), 469 Type II (33,4 %), 63 type III (4,5 %), 439 type IV (31,3 %) and 34 fractures (2,4 %) were unclassified fractures of the femoral head either impactions or comminuted fractures (Fig. 2).

Strategy of emergency treatment

In 35 articles timing of hip dislocation reduction is mentioned and majority of articles understand this as less than 6 h [7–9,11,15–18,21,22,24–34,36–39,41,44–51,53]. The comparative study of 71 patients analysed influence of the timing of the reduction of hip dislocation [19]. Patients were divided into early group (within 6 h after injury) and delayed group (between 6 and 12 h after injury). The incidence of infection, post-traumatic osteoarthritis, and avascular necrosis of the femoral head in the delayed group were significantly higher than that in the early group, which had better functional outcomes in terms of Thompson-Epstein criteria too.

Strategy of definitive treatment

Details regarding definitive treatment were described in 49 articles [6–19,21–55], reporting on 1329 fractures. Majority of them were

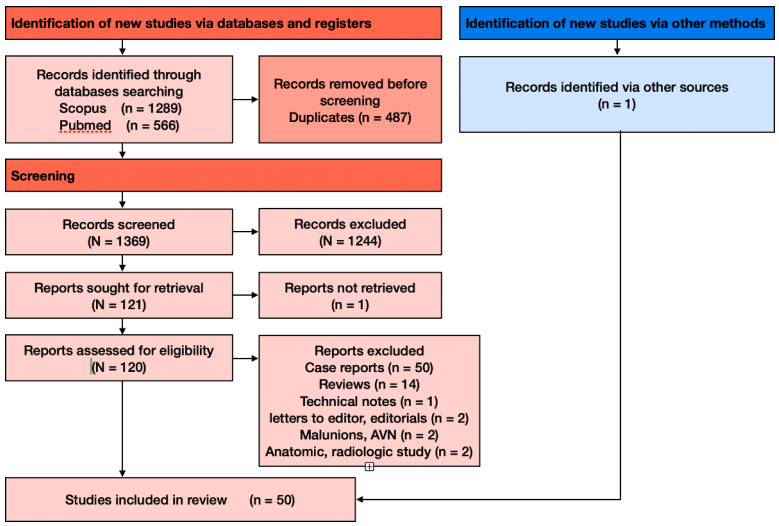

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flowchart.

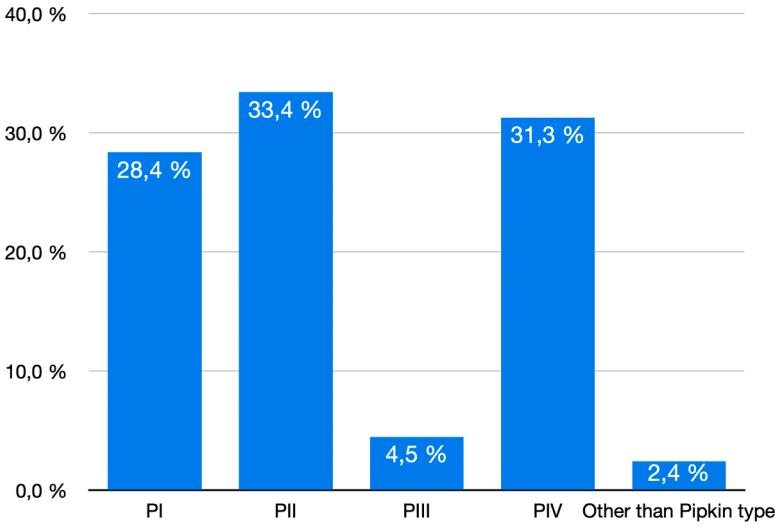

Fig. 2. Distribution of the fracture types according to the Pipkin's classification, among 1403 cases (50 articles).

treated surgically, 1207 (90,8 %), rest of them 122 (9,2 %) conservatively. Preferred surgical treatment for femoral head fractures was reduction and osteosynthesis in 925 (76,7 %) fractures, followed by fragment excision in 222 (18,4 %) cases, THA or HA in 45 (3,7 %) and other technique (mosaicplasty, spacer) 15 (1,2 %) fractures (Fig. 3).

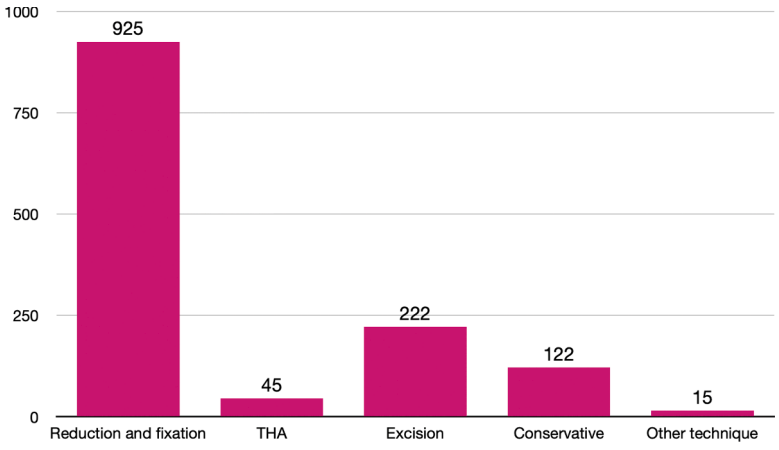

Fig. 3. Treatment strategy in 1329 cases (49 articles).

Surgical approach

The surgical approach to treatment has been the subject of 43 articles on 973 fractures [6–9,13–19,21,23–34,36–49,51–53,55]. The most commonly used approaches were posterior approaches - either the Kocher-Langenbeck approach or one of variant of Ganz flip osteotomy (Gibson or Kocher-Langenbeck interval) in 532 treated fractures (54,7 %). Smith-Petersen or Hueter approach were used in 205 cases (21,1 %). The distribution of surgical approaches used in the treatment is documented in Fig. 4.

Implants used for osteosynthesis

32 articles described implants used for fragment fixation. Screw size was reported in 16 articles [8,9,13,15,24,27–30,32,33,35,36,47,49,51]. In 8 articles, screws from 2.0 to 2.7 mm were used [9,24,28,30,32,35,47,51], and the largest screw diameter reported was 4.5 mm in the minimally invasive technique, where the screw thread ends under the cartilage. In terms of screw design and material used, the Herbert or headless compression screw was most commonly used in 15 of the 17 articles where design was mentioned [13,27,28,30,31,34,36,37,39,40,44–46,48,53]. In 4 studies was used for the fragment fixation bioabsorbable screws in one article described in detail [9,18,38,43]. In one study, fixation of the reduced fragment in three fractures was performed with an osteochondral block taken from the lateral femoral condyle of the ipsilateral knee through a small arthrotomy, with uncomplicated fracture healing and a mean HHS score of 96 points after a mean follow-up of 56 months [25].

Functional outcome

The most broadly used method is the criteria established by Thompson and Epstein [56], made up the functional assessment tool in 24 articles describing 586 treated femoral head fractures [9–12,14–17,19,21–24,26,27,29,31,38,40,41,43,45,52,53]. In 11 articles authors evaluated their cases according to Harris Hip Score - functional score [57], which is based on pain, function, absence of deformity and ROM for a total maximum of 100 points [7,15,25,29–31,37,40,43,47,48].

Complications

Complications were reported in 45 articles with 1197 cases [6–12,15–19,21–38,40–53,55]. The most common complication was heterotopic ossification with 184 cases (15,4 %), followed by post-traumatic arthritis in 115 cases (8,9 %), avascular necrosis in 105 cases (8,8 %) and fracture-related infection – in 8 cases (0,7 %). Secondary THA was required in 89 cases (7,4 %).

In depth analysis of surgical approaches

From 42 articles, where surgical approach was described, selection criteria for detailed analysis fulfilled 38 articles with 856 fractures, which were analysed in detail [6,8,9,14–21,23–32,34,36–40,42–49,51,53,55]. The data obtained from the analysis are summarised in Table 1.

Pipkin fracture types distribution and used approach

Data about Pipkin Fracture Type treated by specific surgical approach were collected from 31 articles regarding 629 fractures [6,7,9,16–18,20,21,23–29,31,32,36–40,42–47,49,51,53]. The distribution of approaches used for each type of Pipkin's fracture and the proportion of Pipkin's fracture types in each surgical approach are documented in the Table 1, Fig. 5,6.

Functional results

The analysis of the functional results in relation to the approach used with the functional score system of Thompson and Epstein was carried out on 295 cases from 17 articles. There was a higher rate of excellent results with the minimally invasive approach and the flip osteotomy (57,1 % resp. 54,4 %) than in medial or Kocher-Langenbeck approach (24,2 % and 28,7 %).

A specific comparison of the functional outcomes of Pipkin type I fractures that were treated either by excision or by ORIF was made from the 12 articles in which this information was available [9,12,16,17,21,23,26,27,31,36,40,42]. 28 fractures were treated with fragment excision, 112 with reduction and fixation. The rate of excellent or good results were similar (78,6 % excision, 73,2 % ORIF) in both groups.

Comparison of T-E functional outcome of Pipkin type I and II fractures with relation to used approach was performed for 177 fractures of 14 studies [9,12,16–18,21,23,24,26,27,29,31,40,42]. For this group of fractures, the functional results were slightly better for the anterior approaches, but when the good and excellent results were combined into one group, the results were better for the posterior approaches, data in Table 2.

The worst functional results were seen in the Pipkin type III group. In the group of 23 fractures, where functional result was available, there was only one excellent result, 8 good, 4 fair and 10 poor results [14,23,27,43,45,52].

Complications

33 articles (538 cases) [6–9,15–17,23–32,34,36–38,40,42–49,51,53,55] describe surgical approach together with complications. The data from these studies were analysed and compared in detail in terms of the surgical approach used and the type of complication. (Tables 1, 3, Figs. 7,8). Statistical analysis showed different incidence of serious complications depending on the approach used. Odds ratio analysis showed 2.81 times lower incidence of AVN in trochanteric-flip osteotomy than in anterior exposure, $p = 0.008$, same analysis demonstrated 2.19 times lower incidence of AVN compared to classic Kocher-Langenbeck, $p = 0.048$. Similarly the rate of heterotopic ossifications (all Brooker stages) was 1.88 times lower in flip osteotomy than in anterior exposures, $p = 0.013$.

In-depth analysis of complications was performed for the Pipkin Type III group. 15 articles in our review deal with this rare and most serious fracture, together 63 cases and 51 cases followed more than 6

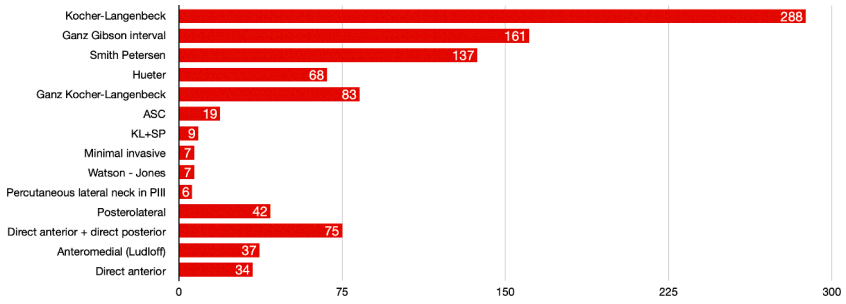

Fig. 4. Surgically treated fractures relating to surgical approach in 973 cases (43 articles).

Table 1
In-depth analysis of Pipkin types, surgical strategy, functional outcomes and major complications related to the surgical approach, 856 cases from 38 articles.

Approach	Pipkin types					Strategy			Functional result TE					FR HHS		Major complications			PTA	FRI	*sec* THA
	N	I	II	III	IV	Other	N	Reduction + fixation	Excision	Other	N	E	G	F	P	N	Mean	N	AVN	HO			
Miniinvasive	7	2	5	0	0	0	7	7	0	0	7	4	2	1	0	7	98.1	7	0	2	1	0	0
ASC	15	10	5	0	0	0	15	15	0	0	0	0	0	0	0	12	92.3	15	0	0	1	0	0
Flip osteotomy	225	36	89	2	91	7	217	200	5	12	68	37	13	12	6	48	86.2	209	13	41	17	3	18
Anterior	129	62	61	1	5	0	177	164	13	0	92	44	26	12	10	8	N	103	18	38	24	0	6
Medial	33	29	4	0	0	0	33	28	5	0	33	8	15	5	5	33	83.3	33	2	1	7	0	4
Kocher Langenbeck	138	15	20	12	91	0	192	145	47	0	94	27	31	16	20	12	62.8	154	24	30	37	0	14
Lateral Hardinge	9	0	0	0	9	0	9	9	0	0	N	N	N	N	N	N	N	9	1	0	0	0	1
Combination KL SP	9	0	0	0	9	0	8	8	0	0	N	N	N	N	N	8	92.1	8	0	0	0	0	0
Combination DA DP	64	0	0	0	64	0	64	64	0	0													
Total	629	154	184	15	269	7	722	640	70	12	294	120	87	46	41	128	79.5	538	58	112	87	3	43
Total%	100.0	24.5	29.3	2.4	42.8	1.1 %	100.0	88.6 %	9.7 %	1.7 %		40.8	29.6	15.6	13.9				10.8	20.8	16.2	0.6	8.0
	%	%	%	%	%		%					%	%	%	%				%	%	%	%	%

ASC: arthroscopy, KL: Kocher Langenbeck, SP: Smith Petersen, DA: Direct Anterior, DP: Direct Posterior, TE: Thompson Epstein, FR: Functional result, HHS: Harris Hip Score, AVN: Avascular necrosis, HO: heterotypic ossification, PTA: Posttraumatic Arthritis, FRI: Fracture Related Infection, THA: Total Hip Arthroplasty.
n - number of cases.

months [14,18,19,22,23,27,32–35,43,45,50,52]. In this group of fractures is observed the highest rate of primary THA, 10 cases (16 %) and also the highest incidence of serious complications - AVN was presented in 33 cases (65 %), in 23 cases (45 %) secondary THA was necessary.

Discussion

Fracture dislocation of the femoral head is an uncommon injury, and an in-depth analysis of current practice is relatively difficult due to small numbers of patients in individual studies, inconsistent assessment of functional outcomes, and a small number of high-quality studies. In depth analysis was then possible only for less than half of the fractures.

Of the 50 studies analysed, only four were randomised control trials, and the rest were retrospective case series. Distribution of individual Pipkin fracture types was almost the same as in the last systematic review [1], except for type 3 fractures, which were two times fewer.

Strategy of emergency treatment

Reduction should be performed under general anaesthesia with muscle relaxation. There is no consensus on whether hip reduction should be performed in the emergency department or in the operating theatre. Reduction of hip dislocation up to 6 h results in less infection rate, posttraumatic osteoarthritis and avascular head necroses [19]. The advantage of an available operating theatre is increased in the case of irreducible hip dislocations, when an open reduction can be performed immediately after an unsuccessful hip reduction. If an experienced team is available for definitive treatment, emergent ORIF can improve functional outcomes and shorten hospital stays [21].

Definitive treatment strategy

Decision between conservative and operative treatment

In comparison with last systemic review [1], increased rate of surgically treated cases can be seen. Conservatively were treated 9.2 % comparing with 22.9 % in last systemic review [1]. The results of an RCT comparing conservative and surgical treatment of Pipkin type I fractures showed that the outcome of the conservative group was worse than that of the surgical group in which the fragments were removed ($p = 0.032$) [17]. Another study reported significantly better outcomes and lower complication rates in the surgical group than in the conservative group in a comparison of Pipkin type II fractures treated either conservatively or surgically with ORIF using the Smith-Petersen approach [42]. In metaanalysis of Pipkin Type I fractures conservative treatment with closed reduction alone for the dislocated hip joint increased the rate of posttraumatic arthritis as well as leading to poor Merle' d Aubigne and Postel outcome scores [58]. In both RCTs, the displacement of the fractures does not play a role in the decision among strategies.

The conservative treatment strategy is therefore generally accepted for non-displaced or minimally displaced fractures, that are "stable" and usually consists of applying traction to the injured limb for a period of 4–8 weeks. Exceptionally immediate toe-touch weight bearing for 6 weeks with early range of motion encouraged, limited to 70° flexion, neutral adduction, and neutral internal rotation was allowed together in 7 cases [11,26]. Assessing how stable these fractures are and preventing complications remains challenging. The mini-invasive percutaneous osteosynthesis described in the case report and in the observational study seems to be an ideal solution for these cases, even in situations where there is residual fragment displacement that can be resolved by arthroscopic or percutaneous techniques[15,59,60]. Confirmation of the quality of reduction can be done by high-level quality C arm, O-arm or ISO-3D directly in the OP theatre and with following percutaneous fixation. Achieved stability is probably lower in comparison with traditional fixation from the fragment to the head, however acceptable for active physiotherapy. The most important seems technique of reduction of the hip dislocation leading to best achievable position of the head

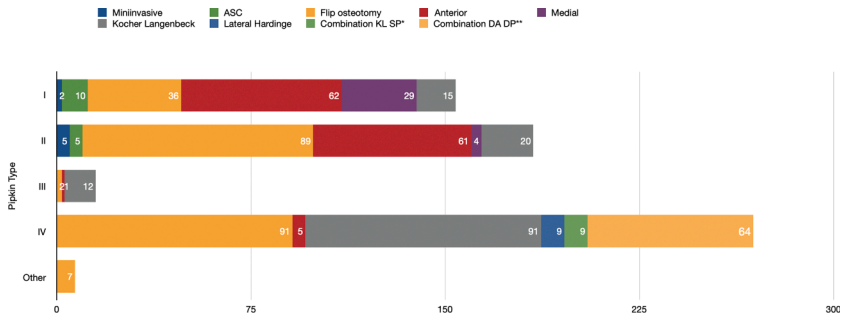

Fig. 5. Number of fractures in groups of Pipkin fractures treated with each approach in 629 femoral head fractures.

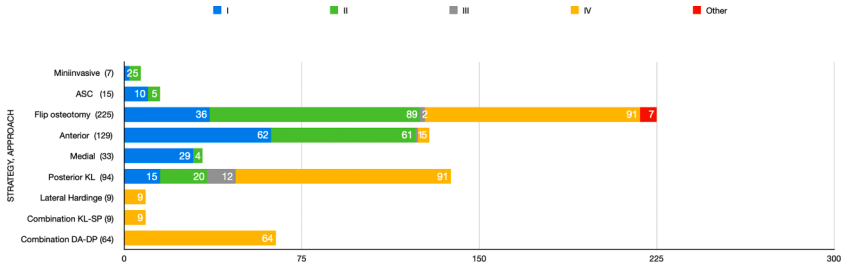

Fig. 6. Treatment of different types of Pipkin fractures relating to surgical approach on 629 cases (31 articles).

Table 2
Comparison of T-E functional results of ORIF from anterior and posterior approaches in Pipkin Type I and II fractures from 177 fractures of 14 studies.

	Pipkin I					Pipkin II					Pipkin *I*+II				
	N	Excellent	Good	Fair	Poor	N	Excellent	Good	Fair	Poor	N	Excellent	Good	Fair	Poor
ANTERIOR approaches	89	30	33	14	12	28	14	8	4	2	138	56	47	20	15
		34 %	37 %	16 %	13 %		50 %	29 %	14 %	7 %		41 %	34 %	14 %	11 %
POSTERIOR approaches	8	3	3	2	0	13	0	10	1	2	39	12	19	5	3
		38 %	38 %	25 %	0 %		0 %	77 %	8 %	15 %		31 %	49 %	13 %	8 %
All approaches	97	33	36	16	12	41	14	18	5	4	177	68	66	25	18
		34 %	37 %	16 %	12 %		34 %	44 %	12 %	10 %		38 %	37 %	14 %	10 %

Table 3
Major late complications in relation to the surgical approach performed, from 33 articles—538 cases.

Complication	Miniinvasive (*n* = 7)	ASC (*n* = 15)	Flip osteotomy (*n* = 209)	Anterior (*n* = 103)	Medial (*n* = 33)	Kocher Langenbeck (*n* = 154)	Lateral Hardinge (*n* = 9)	KL-SP combination (*n* = 8)	TOTAL (*n* = 538)
AVN	0 (0.0 %)	0 (0 %)	13 (6.2 %)	18 (17.5 %)	2 (6.1 %)	24 (15.6 %)	1 (11.1 %)	0 (0.0 %)	49 (9.9 %)
Heterotopic ossification	2 (28.6%)	0 (0 %)	41 (19.6 %)	38 (36.9 %)	1 (3.0 %)	30 (19.5 %)	0 (0.0 %)	0 (0.0 %)	112 (22.7 %)
Arthritis	1 (14.3 %)	1 (6,7 %)	17 (8.1 %)	24 (23.3 %)	7 (21.2 %)	37 (24.0 %)	0 (0.0 %)	0 (0.0 %)	75 (15.2 %)
Fracture related infection	0 (0.0 %	0 (0.0 %)	3 (1.4 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)	3 (0.6 %)
Total	3 (42.9 %)	1 (6,7 %)	74 (37.8 %)	80 (77.7 %)	10 (36.4 %)	91 (59.1 %)	1 (11.1 %)	0 (0.0 %)	

ASC: arthroscopy, Anterior = Hueter, Smith-Petersen, KL: Kocher-Langenbeck, SP: Smith-Petersen, AVN: avascular necrosis, FRI: fracture related infection.
n = number of cases.

fragments. Allis technique in general anaesthesia with muscle relaxation used in observational study led to almost ideal reduction in majority of Pipkin fractures in the time period [15].

Decision between reduction and fixation, excision or THA(HA) in specific pipkin fracture type

Pipkin type i. Comparison of results between ORIF and excision showed statistically non-significantly better T-E functional results for the excision strategy. (78,6 % /73,2 %-excision /ORIF strategy excellent or good results). Tsai analysed 8 articles with 97 cases of Pipkin Type I fracture, where excision was performed in 45 cases. The results indicate that fragment excision had better functional outcomes in terms of both Thompson Epstein and Merle' d Aubigne and Postel scores when compared to ORIF [58]. Giannoudis et al. reported that among 71 Pipkin Type I femoral head fractures, patients who underwent fractured fragment excision reported an 86.7 % "excellent" or "good" Thomson-Epstein functional outcome scores [1]. Based on these findings, excision of the fractured fragment appears to be a simpler solution with minimally similar or even better results. Majority of cases of this type of fracture is treated from anterior approaches, either Hueter,

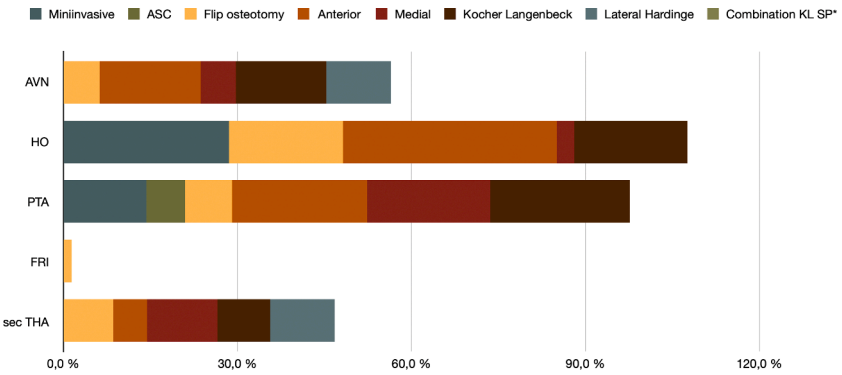

Fig. 7. distribution of complication rate in relation to used surgical approach in 538 cases (33 articles).

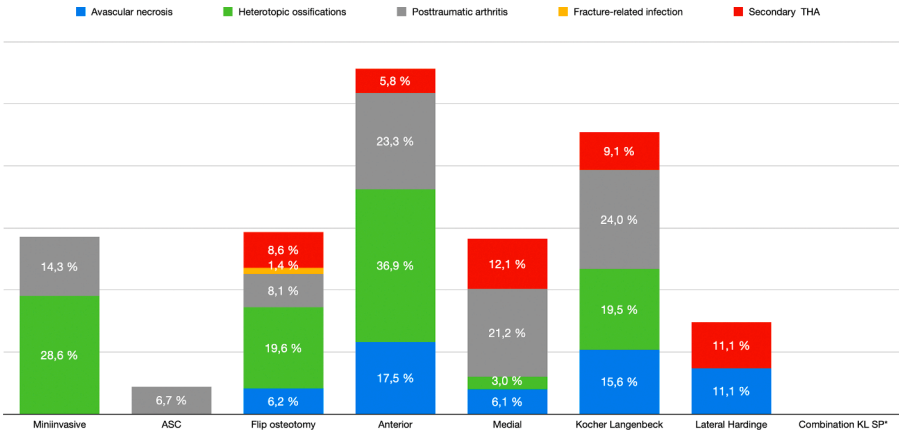

Fig. 8. rate of major late complications in each approach group in%, 538 cases (33 articles).

Smith- Petersen or medial Ludloff approach, described first by Ferguson or Chiron [61,62]. Its use for the treatment of the infra-foveal femoral head fractures was reported in 3 articles [31,33,40], in two of them details about fracture types, treatment and functional results are mentioned [31,40]. The need for a surgeon familiar with this anatomical area and the risk of serious complications didn't allow a wider extension of this strategy.

Arthroscopically assisted osteosynthesis of 5 Pipkin Type I fractures reported interesting functional results (return of all patients to previous occupation or 90 points average HHS), disadvantageous seems long operation time in study of Hsu [8,30]. Minimally invasive treatment with percutaneous osteosynthesis combines the advantages of conservative and operative treatment. It appears to be another good choice for either non-displaced or congruent head fractures after reduction of hip dislocation[15,63,64].

Pipkin type ii. The vast majority of these fractures were operated with fixation of the fragment. Although the most frequent fracture can be reconstructed almost from all surgical approaches to the hip joint, an increasing tendency towards the use of posterior approaches can be observed, especially flip osteotomy. In our in-depth analysis of 626 cases involving 184 Pipkin Type II fractures flip osteotomy or classical Kocher Langenbeck approach were used in 109 cases (59,2 %), Smith-Petersen or Hueter approach in 61 cases (33,2 %). Flip osteotomy is represented in more than 80 % of posterior approaches. Almost complete 360° view on the femoral head and working directly in the area of the injury are the most commonly highlighted advantages [65]. In the Giannoudis review, this approach was used in about 20 % of all cases with surgical treatment. In our analysis, this rate increased to 25.1 %. Percutaneous osteosynthesis may be an option if the position of the fragments is favourable after reduction of hip dislocation [15].

Pipkin type iii. In this rare type of fractures (in our review 4,5 %) rate of AVN and complications in reconstruction strategy is incomparably higher in majority of studies, when AVN developed in 33 cases and secondary THA was necessary in 23 cases. In one study all Pipkin III fractures ($n = 5$) with follow-up greater than 6 months proceeded to catastrophic failure or avascular necrosis [35]. Similarly all 3 Pipkin Type III fractures treated by reconstruction ended with secondary THA in another study [33]. As for the young patients (up to 30–35 years) attempt for saving the hip joint should be always performed, indication for the reconstruction in the patients in the middle age group should be decided much more carefully.

Pipkin type iv. The vast majority of combined fractures of the femoral head and acetabulum were treated from the single posterior approach either with or without flip osteotomy (138 cases of 225). Combination of posterior and anterior approach is another possibility, as majority of head fractures are located on the anterior part of the femoral head and fixation can be demanding from classical Kocher-Langenbeck or Gibson approach. Advance of almost complete view on the femoral head together with reconstruction of fractured acetabulum is the main advantage of increasingly popular Ganz approach in this type of femoral head fracture.

Choice of the approach

The question of which operative approach should be used for the surgical treatment of femoral head fractures is still a matter of discussions. Previously published studies have often shown conflicting results, and this partially remains the case in our review. Although the influence of the type of fracture treated cannot be excluded, comparative studies or studies that focus on one type of fracture reveal interesting facts about

the approaches used. A comparison of the modified Hueter approach and the Kocher-Langenbeck approach in the treatment of Pipkin type I and II femoral head fractures showed differences only in operative time and blood loss, functional outcome and complication rate were almost the same [16]. Another study brought similar results of standard Kocher-Langenbeck and flip osteotomy performed through Gibson interval, when flip osteotomy was associated with shorter operative time, less blood loss and improved visualisation facilitating direct screw fixation compared to Kocher-Langenbeck approach, functional outcome and complication rate were similar [41]. Regarding fact, that majority of departments treat this type of injury only a few times a year, it seems to be a wise strategy to have one approach from which all types of fractures can be treated. Considering the functional results and the number of complications, for the fractures with residual displacement after reduction of hip dislocation Ganz surgical hip dislocation seems to be the ideal solution.

Conclusions

Over the last 20 years, the growing interest in the field has been reflected in an increasing number of publications with important findings. Conservative treatment recedes into the background. Ganz flip osteotomy with surgical hip dislocation allows safe treatment of all types of fractures and should be kept in mind as first choice method. The individuality of the patient and appropriate experience with the chosen strategy should not be overlooked.

General therapeutic approach

The following therapeutic approach can be recommended on the basis of the information found and the statistical analyses carried out: femoral head fracture-dislocation Pipkin Type I and II should be reduced in general anaesthesia urgently within 6 h, ideally in OP theatre. The quality of the reduction should be assessed using C-arm, ISO 3D or O-arm, and if the reduction appears anatomical, percutaneous fixation with radiographic or ASC control can be an advantageous choice. If the residual displacement is greater than 1.5 mm, ORIF by trochanteric flip osteotomy or from Hueter/Smith-Petersen approach is recommended in Pipkin type II and excision of the fragment in Pipkin type I fracture. In Pipkin type III, reconstruction should only be attempted in very young patients up to 35–40 years of age, in older patients THA should be performed as “one shot surgery”. In Pipkin type IV fracture a Ganz approach should be preferred. The recommened treatment algorithm is illustrated in Fig. 9.

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CRediT authorship contribution statement

Martin Kloub: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Pavel Látal:** . **Peter Giannoudis:** Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

There was no conflict of interest.

Appendix 1. OECBM level of evidence and GRADE assessment of studies included in the review

Author	Design of study	OCEBM level of evidence [4]	GRADE assessment [5]
Wang et al. [6]	Prospective case series	Level IV	Low
Lian et al. [7]	Retrospective case series	Level IV	Low

(*continued on next page*)

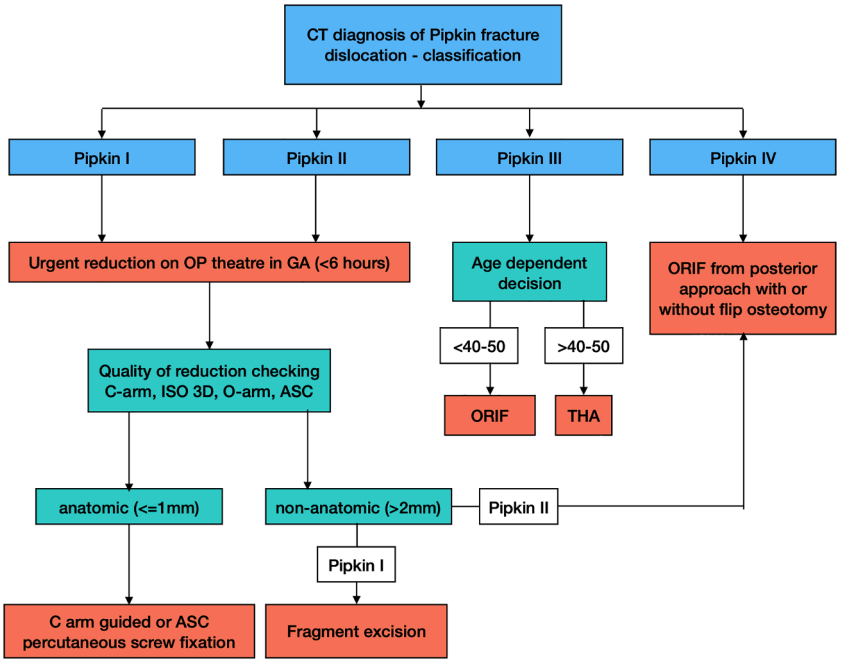

Fig. 9. Recommended treatment algorithm for femoral head fracture-dislocation according to Pipkin Type classification.

(*continued*)

Author	Design of study	OCEBM level of evidence [4]	GRADE assessment [5]
Park et al. [8]	Retrospective case series	Level IV	Low
Prokop et al. [9]	Retrospective case series	Level IV	Low
Yoon et al. [10]	Retrospective case series	Level IV	Low
Core et al. [11]	Retrospective case series	Level IV	Low
Park et al. [12]	Retrospective case series	Level IV	Low
Sun et al. [13]	Randomized control trial	Level II	Moderate
Yu et al.[14]	Retrospective case series	Level IV	Low
Kloub et al. [15]	Retrospective case series	Level IV	Low
Wang et al. [16]	Retrospective case series	Level IV	Low
Chen et al. [17]	Randomized control trial	Level II	Moderate
Kokubo et al. [18]	Retrospective case series	Level IV	Low
Wang et al. [19]	Retrospective case series	Level IV	Low
Liu[20]	Randomized control trial	Level III	Low
Lin et al. [21]	Randomized control trial	Level II	Moderate
Mostafa [22]	Retrospective case series	Level IV	Low
Kloen et al. [23]	Retrospective case series	Level IV	Low
Henle et al. [24]	Retrospective case series	Level IV	Low
Gagala et al. [25]	Retrospective case series	Level IV	Low
Oransky et al. [26]	Retrospective case series	Level IV	Low
Stannard et al. [27]	Retrospective case series	Level IV	Low
Gavaskar et al. [28]	Retrospective case series	Level IV	Low
De Mauro et al. [29]	Retrospective case series	Level IV	Low
Hsu et al. [30]	Retrospective case series	Level IV	Low
Wang et al. [31]	Retrospective case series	Level IV	Low
Lai et al. [55]	Retrospective case series	Level IV	Low
Mehta et al. [32]	Retrospective case series	Level IV	Low
Tonetti et al. [33]	Retrospective case series	Level IV	Low
Shakya et al. [34]	Retrospective case series	Level IV	Low
Scolaro et al. [35]	Retrospective case series	Level IV	Low
Hosny et al. [36]	Retrospective case series	Level IV	Low
Khalifa et al. [37]	Retrospective case series	Level IV	Low
Wang et al. [38]	Retrospective case series	Level IV	Low
Trikha et al. [39]	Retrospective case series	Level IV	Low
Abdelazeem et al. [40]	Retrospective case series	Level IV	Low
Mostafa et al. [41]	Retrospective case series	Level IV	Low
Chen et al. [42]	Randomized control trial	Level II	Moderate
Enocson et al. [54]	Retrospective case series	Level IV	Low
Wang et al. [43]	Retrospective case series	Level IV	Low
Engel et al. [44]	Retrospective case series	Level IV	Low
Yoon et al. [45]	Retrospective case series	Level IV	Low
Gavaskar et al. [46]	Retrospective case series	Level IV	Low
Massé et al. [47]	Retrospective case series	Level IV	Low
Aprato et al. [48]	Retrospective case series	Level IV	Low
Yu et al. [49]	Retrospective case series	Level IV	Low
Peng et al. [50]	Retrospective case series	Level IV	Low
Hanke et al. [51]	Retrospective case series	Level IV	Low
Pascarella et al. [52]	Retrospective case series	Level IV	Low
Solberg et al. [53]	Retrospective case series	Level IV	Low

References

[1] Giannoudis PV, Kontakis G, Christoforakis Z, Akula M, Tosounidis T, Koutras C. Management, complications and clinical results of femoral head fractures. Inj 2009;40:1245–51. https://doi.org/10.1016/j.injury.2009.10.024.

[2] Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;339: b2535. https://doi.org/10.1136/bmj.b2535.

[3] Higgins JPT, Thomas J, ChandlerJ CM, Li T, Page MJ, Welch VA, editors. Cochrane handbook for systematic reviews of interventions. 2nd Edition. Chichester (UK): John Wiley & Sons; 2019.

[4] Howick J., Chalmers I., Glasziou P., Greenhalgh T., Heneghan C., Liberati A., Moschetti I., Phillips B., Thornton H. (2011) The 2011 Oxford CEBM levels of evidence (introductory document) 2011. https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence.

[5] Siemieniuk R. and Guyatt G. (n.d.) What is GRADE? BMJ Best Practice. https://bestpractice.bmj.com/info/us/toolkit/learn-ebm/what-is-grade/Accessed 30 Mar 2023.

[6] Wang J, Cai L, Xie L, Chen H, Guo X, Yu K. 3D printing-based Ganz approach for treatment of femoral head fractures: a prospective analysis. J Orthop Surg Res 2019;14:338. https://doi.org/10.1186/s13018-019-1383-7.

[7] Lian S, Yang Z, Hu Z, Mu W. A combination of the K-L and S-P approaches for treating acetabular posterior wall factures accompanied by femoral head fractures with open reduction and internal fixation. Bmc Surg 2022;22:165. https://doi.org/10.1186/s12893-022-01597-w.

[8] Park MS, Yoon SJ, Choi SM. Arthroscopic reduction and internal fixation of femoral head fractures. J Orthop Trauma 2014;28:e164–8. https://doi.org/10.1097/bot.0000000000000048.

[9] Prokop A, Helling HJ, Hahn U, Udomkaewkanjana C, Rehm KE. Biodegradable implants for pipkin fractures. Clin Orthop Relat R 2005;432:226–33. https://doi.org/10.1097/01.blo.0000150374.46728.54.

[10] Yoon TR, Rowe SM, Chung JY, Song EK, Jung ST, Anwar IB. Clinical and radiographic outcome of femoral head fractures: 30 patients followed for 3-10 years. Acta Orthop 2001;72:348–53. https://doi.org/10.1080/000164701753541998.

[11] Core MAD, Gross B, Ahn J, Wallace SB, Starr A. Clinical and radiographic outcomes of femoral head fractures associated with traumatic hip dislocations. Strategies Trauma Limb Reconstr 2019;14:6–10. https://doi.org/10.5005/jp-journals-10080-1416.

[12] Park KS, Lee KB, Na BR, Yoon TR. Clinical and radiographic outcomes of femoral head fractures: excision vs. fixation of fragment in Pipkin type I: what is the optimal choice for femoral head fracture? J Orthop Sci 2015;20:702–7. https://doi.org/10.1007/s00776-015-0732-6.

[13] Sun Z, Jiang L, Chen R, Zhao L, Li X. Clinical effects of direct anterior internal fixation with Herbert screws on hip joint function and quality of life in patients with Pipkin II femoral head fractures. Arch Orthop Trauma Surg 2023;143:63–70. https://doi.org/10.1007/s00402-021-03973-2.

[14] Yu X, Pang Q, Chen XJ. Clinical results of femoral head fracture-dislocation treated according to the Pipkin classification. Pak J Med Sci 2017;33:650–3. https://doi.org/10.12669/pjms.333.12633.

[15] Kloub M, Holub K, Peml M, Urban J, Látal P. Closed reduction and minimally invasive screw osteosynthesis of Pipkin femoral head fractures. J Appl Biomed 2023;21:1–6. https://doi.org/10.32725/jab.2023.001.

[16] Wang S, Li B, Li J, Zhang Z, Yang H, Liu L. Comparison of the modified Heuter approach and the Kocher-Langenbeck approach in the treatment of Pipkin type I and type II femoral head fractures. Int Orthop 2019;43:2613–20. https://doi.org/10.1007/s00264-019-04301-5.

[17] Chen Z, Lin B, Zhai W, Guo Z, Liang Z, Zheng JP, et al. Conservative versus surgical management of Pipkin type I fractures associated with posterior dislocation of the hip: a randomised controlled trial. Int Orthop 2011;35:1077–81. https://doi.org/10.1007/s00264-010-1087-4.

[18] Kokubo Y, Uchida K, Takeno K, Yayama T, Miyazaki T, Negoro K, et al. Dislocated intra-articular femoral head fracture associated with fracture-dislocation of the hip and acetabulum: report of 12 cases and technical notes on surgical intervention. European J Orthop Surg Traumatology 2013;23:557–64. https://doi.org/10.1007/s00590-012-1027-7.

[19] Wang S, Li B, Zhang Z, Yu X, Li Q, Liu L. Early versus delayed hip reduction in the surgical treatment of femoral head fracture combined with posterior hip dislocation: a comparative study. Bmc Musculoskelet Di 2021;22:1057. https://doi.org/10.1186/s12891-021-04968-1.

[20] Liu B, Zhao B, Zhang Q. Efficacy of direct anterior approach combined with direct posterior approach in Pipkin IV femoral head fractures. J Orthop Surg Res 2022;17:160. https://doi.org/10.1186/s13018-022-03058-9.

[21] Lin D, Lian K, Chen Z, Wang L, Hao J, Zhang H. Emergent surgical reduction and fixation for Pipkin Type I femoral fractures. Orthopedics 2013;36:778–82. https://doi.org/10.3928/01477447-20130523-24.

[22] Mostafa MM. Femoral head fractures. Int Orthop 2001;25:51–4. https://doi.org/10.1007/s002640000209.

[23] Kloen P, Siebenrock KA, Raaymakers ELFB, Marti RK, Ganz R. Femoral head fractures revisited. European J Trauma 2002;28:221–33. https://doi.org/10.1007/s00068-002-1173-4.

[24] Henle P, Kloen P, Siebenrock KA. Femoral head injuries: which treatment strategy can be recommended? Inj 2007;38:478–88. https://doi.org/10.1016/j.injury.2007.01.023.

[25] Gagaa J, Tarczyska M, Gawda K. Fixation of femoral head fractures with autologous osteochondral transfer (Mosaicplasty). J Orthop Trauma 2014;28:e226–30. https://doi.org/10.1097/bot.0000000000000079.

[26] Oransky M, Martinelli N, Sanzarello I, Papapietro N. Fractures of the femoral head: a long-term follow-up study. Musculoskelet Surg 2012;96:95–9. https://doi.org/10.1007/s12306-012-0182-7.

[27] Stannard JP, Harris HW, Volgas DA, Alonso JE. Functional outcome of patients with femoral head fractures associated with hip dislocations. Clin Orthop Relat R 2000;377:44–56. https://doi.org/10.1097/00003086-200008000-00008.

[28] Gavaskar AS, Tummala NC. Ganz surgical dislocation of the hip is a safe technique for operative treatment of Pipkin fractures. Results of a prospective trial. J Orthop Trauma 2015;29:544–8. https://doi.org/10.1097/bot.0000000000000399.

[29] Mauro DD, Rovere G, Smakaj A, Marino S, Ciolli G, Perna A, et al. Gibson approach and surgical hip dislocation according to Ganz in the treatment of femoral head fractures. Bmc Musculoskelet Di 2021;22:961. https://doi.org/10.1186/s12891-021-04800-w.

[30] Hsu SL, Chen CY, Ko JY, Hsu CH, Liu HC, Lu YD. Hip arthroscopy-assisted reduction and fixation for femoral head fracture dislocations: clinical and radiographic short-term results of seven cases. J Orthop Surg-Hong K 2019;27:2309499019881865. https://doi.org/10.1177/2309499019881865.

[31] Wang Z, Li K, Zhao P, Chen E, In Zheng J. Situ Reduction and fixation of the anterior medial fenestration approach for femoral head fracture. Orthop Surg 2019;11:1163–72. https://doi.org/10.1111/os.12578.

[32] Mehta S, Routt MLC. Irreducible fracture-dislocations of the femoral head without posterior wall acetabular fractures. J Orthop Trauma 2008;22:686–92. https://doi.org/10.1097/bot.0b013e31818e2a86.

[33] Tonetti J, Ruatti S, Lafontan V, Loubignac F, Chiron P, Sari-Ali H, et al. Is femoral head fracture-dislocation management improvable: a retrospective study in 110 cases. Orthop Traumatology Surg Res 2010;96:623–31. https://doi.org/10.1016/j.otsr.2010.03.020.

[34] Shakya S, Chen J, Sun J, Xiang Z. Management and outcome of patients with femoral head fractures: the mid-term follow-up with injuries and associated prognostic factors. BMC Musculoskelet Disord 2023;24:311. https://doi.org/10.1186/s12891-023-06317-w.

[35] Scolaro JA, Marecek G, Firoozabadi R, Krieg JC, Routt ML. "Chip." Management and radiographic outcomes of femoral head fractures. J Orthop Traumatology 2017;18:235–41. https://doi.org/10.1007/s10195-017-0445-z.

[36] Hosny H, Mousa S, Salama W. Management of femoral head fracture by Ganz surgical dislocation of the hip. J Orthop Traumatology 2022;23:24. https://doi.org/10.1186/s10195-022-00643-w.

[37] Khalifa AA, Refai O, Farouk O, Abdelnasser MK. Management of femoral head fractures through surgical hip dislocation (SHD): a demanding but safe technique. Arch Orthop Trauma Surg 2021;141:1701–10. https://doi.org/10.1007/s00402-020-03666-2.

[38] Wang SX, Li BH, Li J, Huang FG, Xiang Z, Zhong G, et al. Middle-term follow-up results of Pipkin type IV femoral head fracture patients treated by reconstruction plate and bioabsorbable screws. Chin J Traumatology 2018;21:170–5. https://doi.org/10.1016/j.cjtee.2017.12.004.

[39] Trikha V, Das S, Madegowda A, Agrawal P. Midterm results of trochanteric flip osteotomy technique for management of fractures around the hip. HIP Int 2017;28:148–55. https://doi.org/10.5301/hipint.5000539.

[40] Abdelazeem A, Fahmy M, Abdelazeem H. Modified Ludloff's medial approach for management of Pipkin's type I femoral head fracture. Int Orthop 2021;45:1591–8. https://doi.org/10.1007/s00264-020-04667-x.

[41] Mostafa MF, El-Adl W, El-Sayed MAE. Operative treatment of displaced Pipkin type I and II femoral head fractures. Arch Orthop Trauma Surg 2014;134:637–44. https://doi.org/10.1007/s00402-014-1960-5.

[42] Chen Z, Zhai W, Ding Z, Lian K, Kang L, Guo L, et al. Operative versus nonoperative management of Pipkin Type-II fractures Associated with posterior hip dislocation. Orthopedics 2011;34:350. https://doi.org/10.3928/01477447-20110317-09.

[43] Wang S, Yu X, Li B, Ding Q, Wang T, Li Q, et al. Pipkin type III femoral head fracture: which treatment strategy can be recommended? J Orthop Traumatol 2023;24:28. https://doi.org/10.1186/s10195-023-00701-x.

[44] Engel JL, Johnsen P, Patel NK, Satpathy J, Mounasamy V. Pipkin type IV femoral head fractures: a case series and review of literature. European J Orthop Surg Traumatology 2021;31:791–5. https://doi.org/10.1007/s00590-020-02838-5.

[45] Yoon YC, Oh CW, Kim JW, Heo J, Song HK. Safety of surgical hip dislocation in femoral head fracture and dislocation (FHFD) and avascular necrosis risk factor analysis of FHFD: midterm results confirmed by SPECT/CT and MRI. J Orthop Surg Res 2022;17:278. https://doi.org/10.1186/s13018-022-03160-y.

[46] Gavaskar AS, Srinivasan P, Jeyakumar B, Raj RV, Sharath V, AN D. Surgical dislocation or the modified heuter anterior approach for pipkin I and II femoral head fracture dislocations. J Orthop Trauma 2020;34:626–31. https://doi.org/10.1097/bot.0000000000001877.

[47] Massè A, Aprato A, Alluto C, Favuto M, Ganz R. Surgical hip dislocation is a reliable approach for treatment of femoral head fractures. Clin Orthop Relat R 2015;473:3744–51. https://doi.org/10.1007/s11999-015-4352-4.

[48] Aprato A, Buzzone M, Benedetto PD, Massè A. Surgical HIP dislocation vs arthroscopy for fixation of subfoveal femoral head fractures. Acta Bio Medica Atenei Parmensis 2021;92:e2021016. https://doi.org/10.23750/abm.v92is3.11724.

[49] Yu YH, Hsu YH, Chou YC, Tseng IC, Su CY, Wu CC. Surgical treatment for Pipkin type IV femoral head fracture. J Orthop Surg-Hong K 2017;25:2309499016684970. https://doi.org/10.1177/2309499016684970.

[50] Peng SH, Wu CC, Yu YH, Lee PC, Chou YC, Yeh WL. Surgical treatment of femoral head fractures. Biomed J 2020;43:451–7. https://doi.org/10.1016/j.bj.2019.08.004.

[51] Hanke MS, Keel MJB, Cullmann JL, Siebenrock KA, Bastian JD. Transfer of osteochondral shell autografts to salvage femoral head impaction injuries in hip trauma patients. Injury 2020;51:711–8. https://doi.org/10.1016/j.injury.2020.01.037.

[52] Pascarella R, Fantasia R, Sangiovanni P, Maresca A, Massetti D, Politano R, et al. Traumatic hip fracture-dislocation: a middle-term follow up study and a proposal of new classification system of hip joint associated injury. Inj 2019;50:S11–20. https://doi.org/10.1016/j.injury.2019.01.011.

[53] Solberg BD, Moon CN, Franco DP. Use of a trochanteric flip osteotomy improves outcomes in Pipkin IV fractures. Clin Orthop Relat R 2009;467:929–33. https://doi.org/10.1007/s11999-008-0505-z.

[54] Enocson A, Wolf O. Pipkin fractures: epidemiology and outcome. Eur J Trauma Emerg S 2022;48:4113–8. https://doi.org/10.1007/s00068-022-01951-w.

[55] Lai PJ, Lai CY, Tseng IC, Su CY, Yu YH. Influence of associated femoral head fractures on surgical outcomes following osteosynthesis in posterior wall acetabular fractures. BMC Musculoskelet Disord 2022;23:830. https://doi.org/10.1186/s12891-022-05777-w.

[56] THOMPSON VP, EPSTEIN HC. Traumatic dislocation of the hip; a survey of two hundred and four cases covering a period of twenty-one years. J Bone Jt Surg Am Vol 1951;33-A:746–78. passim.

[57] Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am 1969;4:737–55.

[58] Tsai SHL, Tai WC, Fu TS, Tischler EH, Rahman R, Lim YK, et al. Does surgical repair benefit Pipkin Type I femoral head fractures?: a systematic review and meta-analysis. Life 2022;12:71. https://doi.org/10.3390/life12010071.

[59] Homma Y, Miyahara S, Mogami A, Morohashi I, Baba T, Kaneko K. Percutaneous screw fixation for a femoral head fracture: a case report. Arch Orthop Trauma Surg 2014;134:371–4. https://doi.org/10.1007/s00402-013-1888-1.

[60] Matsuda DK. A rare fracture, an even rarer treatment: the arthroscopic reduction and internal fixation of an isolated femoral head fracture. Arthrosc J Arthrosc Relat Surg 2009;25:408–12. https://doi.org/10.1016/j.arthro.2009.01.011.

[61] Chiron P, Murgier J, Cavaignac E, Pailhé R, Reina N. Minimally invasive medial hip approach. Orthop Traumatology Surg Res 2014;100:687–9. https://doi.org/10.1016/j.otsr.2014.06.009.

[62] Ferguson AB. Primary open reduction of congenital dislocation of the hip using a median adductor approach. J Bone Jt Surg Am Vol 1973;55:671–89.

[63] Lansford T, Munns SW. Arthroscopic treatment of pipkin type i femoral head fractures. J Orthop Trauma 2012;26:e94–6. https://doi.org/10.1097/bot.0b013e3182323f4f.

[64] Rojas-Sayol R, Caso JD, Valera M. Arthroscopic-assisted percutaneous fixation of a femoral head fracture (Pipkin II). Jbjs Case Connect 2022;12. https://doi.org/10.2106/jbjs.cc.22.00194. e22.00194.

[65] Singh K, Weitlich JD, Zitsch BP, Schweser KM, Cook JL, Crist BD. Which surgical approach provides maximum visualization and access for open reduction and internal fixation of femoral head fractures? J Orthop Trauma 2022;36:S12–6. https://doi.org/10.1097/bot.0000000000002308.