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Review Article

Intraoperative Fractures of Acetabulum and Proximal Femur in Cementless Primary Total Hip Arthroplasty: A Systematic Review

Sajid Ansari[1], Tushar Gupta[1], Anil Regmi[2], Arghya Kundu Choudhury[1], Balgovind S Raja[3], Roop Bhushan Kalia[4*], Debadatta Panda[2], Bishwa Bandhu Niraula[2]

[1]Senior Resident, Department of Orthopaedics, All India Institute of Medical Sciences, Rishikesh, India
[2]Junior Resident, Department of Orthopaedics, All India Institute of Medical Sciences, Rishikesh, India
[3]Assistant Professor, Department of Orthopaedics, All India Institute of Medical Sciences, Patna, India
[4]Additional Professor, Department of Orthopaedics, All India Institute of Medical Sciences, Rishikesh, India
***Correspondence author:** Roop Bhusan Kalia, MBBS, MS, Additional Professor, Department of Orthopaedics, All India Institute of Medical Sciences, Rishikesh, India; Email: roopkalia2003@yahoo.com

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Abstract

Introduction: Cementless Total Hip Arthroplasty (THA) is generally safe, but intraoperative fractures of the acetabulum and proximal femur can occur and can have significant consequences for the patient. This systematic review aims to synthesize the available literature on intraoperative fractures of the acetabulum and proximal femur during primary uncemented THA and highlight the incidence, risk factors, and potential preventive measures for these fractures, to improve patient outcomes and reduce the incidence of this complication.

Methods: We conducted a thorough review in the PUBMED, EMBASE, Cochrane database and Scopus library, and extracted the articles describing the intraoperative acetabulum and femur fractures in primary cementless THA.

Results: The initial search carried out produced 1792 results. After exclusion processing, 22 articles were included for the review. Of these, 16 were intraoperative fractures of the femur and 6 were intraoperative fractures of the acetabulum. Incidence of acetabular fractures was 0.49% and 2.7% for femoral fractures with female preponderance in both groups. Time of occurrence and location of the intra-operative fractures can vary widely, with femoral fractures occurring more commonly during broaching and acetabular fractures during cup implantation.

Conclusion: A plethora of management options have been utilized according to surgeon preference and the fracture pattern as well as location. Standard principles of fracture fixation and arthroplasty should be followed to achieve stable internal fixation and any unstable fracture site should be bypassed with the utilization of long-stemmed components.

Keywords: Total Hip Arthroplasty; Intra-operative Fracture; Acetabular Fractures; Femur Fractures; Systematic Review

Introduction

Total Hip Arthroplasty (THA) is a commonly performed and most effective and successful orthopaedic procedure in reducing pain, restoring function, and improving a patient's overall quality of life for the management of hip arthritis [1]. Hence, the demand for primary cementless THA has increased over the past 20 years and is projected to grow exponentially in the upcoming decade [2]. The complications after cementless THA are also expected to concomitantly increase with the increase in procedural volume [2].

The procedure is generally safe, intraoperative fractures of the acetabulum and proximal femur can occur and can have significant consequences for the patient [3]. These fractures can lead to increased morbidity and mortality, prolonged hospital

stays and a reduced long-term functional outcome. Most complications associated with THA are uncommon, preventable if anticipated, and managed when recognized [4]. A range of risk factors including smaller incision surgery, uncemented components, prior surgery, female sex, osteoporosis, and inflammatory arthritis have been identified [5]. Femoral intraoperative fractures have been reported to be between 0.1% and 1% for cemented and nearly 5% for cementless primary THA, while periprosthetic acetabular fractures are more uncommon, with reported rates as low as 0.4% [4].

Identifying effective preventive measures can help to reduce the incidence of intraoperative fractures, leading to improved patient outcomes and a reduced burden on the healthcare system [6,7]. This systematic review aims to synthesize the available literature on intraoperative fractures of the acetabulum and proximal femur during primary uncemented THA. The review will identify the incidence, risk factors, and potential preventive measures for these fractures, to improve patient outcomes and reduce the incidence of this complication.

Methodology

Methods

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The initial search was conducted on 01 January 2023 in the electronic databases Pubmed, EMBASE, Cochrane library, and Scopus. The search was conducted using the search term using boolean operators "and" and "or" as "intra-operative fractures" and "acetabulum fracture" OR "femoral fracture" and "primary cementless total hip arthroplasty or "primary uncemented total hip arthroplasty".

Eligibility Criteria

All original studies were included if (a) Intraoperative fractures of the femur and/or acetabulum during primary cementless total hip arthroplasty were analysed, (b) Sample size of at least 10 cases and (c) Studies in English language. The exclusion criteria included (a) Case series with less than 10 patients, (b) Studies with duplication of data, (c) Case reports, (d) Registry data and (e) Reviews, Letters to the editor, Editorial reviews and Conference posters.

Data Extraction

The authors SA and AR performed the searches and prepared the list based on the inclusion criteria mentioned below. TG, BBN, and DP authors did the data collection and quality assessment using a standardized form. Any disparity between the authors was discussed, and a final consensus was made by the senior author RBK. The reference list of selected articles and various online journals were searched individually for more studies. Data regarding the authors, year of publication, location of study, study design, sample size, follow-up period, preoperative diagnosis, type of index procedure performed, the approach of THA, number of fractures, site, and location of the fracture, method of diagnosis of fracture, an implant used, management of fracture, revisions, radiological and clinical outcomes were extracted.

Quality Assessment

The quality assessment of the studies was conducted using the Methodological Index for Non-Randomized Studies (MINORs) tool. The authors BSR, AKC and DP performed the quality assessment, any disagreements were discussed, and a final consensus was made.

Results

The initial search carried out produced 1792 results after the elimination of duplicates, leaving 1429 studies. Out of 1429 articles 637 were selected for full-text review and resulted in a final pool of 33 studies. A total of 22 articles were finally included in the study as shown in the PRISMA chart (Fig. 1). Of these 16 were intraoperative fractures of the femur and 6 were intraoperative fractures of the acetabulum [3,5-9,11,13,15-17,19-23-28,31].

Acetabulum Fractures

Patient Characteristics: Six retrospective studies reported intraoperative acetabular fracture during primary total hip arthroplasty on 189 hips [24-28,31]. Haidukewyc, et al., studied 7000 THA with acetabular fractures in 21 hips with an incidence of 0.3% [26]. Hasegawa, et al., studied 406 THA with acetabular fractures in 41 patients with an incidence of 8.4% and Li, et al., reported an

incidence of 0.49% (24/4888) [24,28]. Five studies differentiated the sex of patients for intra-operative acetabular fractures on 124 patients with 42 males and 82 females, with a Male: Female ratio of 1:1.95 (Table 1) [24-27,31].

Preoperative Assessment: Four studies mentioned the pre-operative diagnosis for which the patient had undergone THA in 116 intra-operative acetabulum fracture cases [24-27]. Primary osteoarthritis was found in 69 cases (59.48%), followed by 19 AVN cases (16.3%), 10 hips following developmental dysplasia of the hip (8.62%), 7 Non-union neck of femur (6.34%), 6 ankylosing spondylitis (5.17%), 3 RA (2.58%), and 2 post-traumatic arthritis (1.72%) (Table 1).

Procedure and Approach: The Hybrid THA was performed by Haidukewych, et al., in 17/21 cases and Hasegawa, et al., performed only hybrid THA in 41/41 cases of intra-operative acetabulum fracture [24,26]. Rest studies including Haidukewych, et al., performed uncemented THA in 131 cases [26]. Overall, 30.68% (58/189) of intra-operative acetabular fracture cases were operated by the Hybrid technique and 69.31% (131/189) of cases were operated by the uncemented THR technique.

Haidukewych, et al., mentioned 18 anterolateral and three posterolateral approaches [26]. Rest 2 studies by Hasegawa et al. and Li, et al., operated by postero-lateral approaches [24,28]. Overall, the most common approach was the posterolateral / trans-gluteal approach in (62.5%) 90/144 cases, followed by the direct anterior approach in (25%) 36/144 and anterolateral in (12.5%)18/144 hips (Table 2).

Location of Fracture: Five articles mentioned the sites of fracture except Sharkey, et al., four studies were classified according to Hasegawa, et al., classification on 144 patients, where the most common site encountered is the superolateral wall in 26.38% (38/144), followed by other sites outside the acetabulum in 23.61% (34/144) followed by the posterior wall in 18.75% (27/144), anterior wall in 15.9% (23/144), medial wall in 14.58% (21/144) and unclassified in 0.69% (1/144) [27,24]. Laflamme, et al., classified 13 cases according to Judet and Letournel's classification, anterior wall in 4, medial wall in 7, posterior wall in 9, a posterior column in 6, transverse in 1, and T-type in 1 case (Table 2) [12].

Time of Occurrence and Diagnosis: Dammerer, et al., mentioned that intraoperative fracture was identified in the post-operative phase [29]. Whereas other studies mentioned fracture was identified intra-operatively. Haidukewych, et al., mentioned, in sixteen (76%) of the 21 hips, the fracture was noted during impaction of the real acetabular component in three, it was noted during reaming; and in two, it was noted during initial hip dislocation [26]. Li, et al., reported17 out of 25 fractures during impaction of the real acetabular component, 5 during initial hip dislocation and osteotomy and 1 during reaming [28]. Sharkey, et al., mentioned 13 hips at the time of impaction [27]. Hasegawa, et al., and Laflamme, et al., in (41+32) reported fracture and was diagnosed intra-operatively, but did not actually mention the time of occurrence of fracture [24,25]. Overall, the majority of fractures occurred at the time of impaction.

Hasegawa, et al., used CT scans to diagnose intra-operative acetabular fractures [24]. Laflamme, et al., mentioned that AP and Judet X-rays and CT scans, when available, were used for fracture diagnosis [25]. Haidukewych, et al., mentioned in their study that the fracture was diagnosed clinically [26]. Li, et al., and Sharkey, et al., used fluoroscopy to diagnose fractures (Table 2) [28].

Method of Management and Revision Surgery

Hasegawa, et al., mentioned no additional procedure required for intra-operative fracture management [24]. Haidukewych, et al., replaced the acetabular cup along with supplemental screw fixation in 4 patients with unstable components. No supplemental plates, lag screw or antiprotrusio device was needed in any patients [26]. Li, et al., required two plate fixations and 18 screw fixations, and in 4 patients the fracture was labelled stable and was managed conservatively.[28] Laflamme, et al., required no additional procedure in 16 hips, whereas augmentation with a screw only in 11 hips, and ORIF with posterior plate was required in 5 hips [25]. Sharkey, et al., mentioned screw plus allograft were required in 4 cases, however, other cases required post-operative rehabilitation modification in 2 cases, and no additional intervention was required in 5 hips [27].

Revision surgery was required in 21/189 (11.11%) cases, where Dammerer, et al., mentioned revision surgery in 8 patients (4 for postoperative infection at 2 weeks, 2mo, 10mo, 23mo), 2 for aseptic loosening (at 16mo and 24mo) and cup migration, 2 for protrusion and obvious cup loosening [29]. Haidukewych, et al., mentioned One patient required revision at 2 years [26].

Hasegawa, et al., mentioned 2 cases that had periprosthetic fractures for which a dome screw fixation with both a peripheral self-locking cup and a hemispheric cup was used respectively [24]. Laflamme, et al., mentioned revision surgery was required in 8 hips and Sharkey, et al., mentioned in 2 cases but the details of revision surgery performed was not elaborated in their study (Table 3) [25].

Clinico-Radiological Outcome

Haidukewych, et al., mentioned assessing pain, walking ability, and the need for walking aids, where out of eighteen patients, fifteen had no pain and three had mild trochanteric discomfort [26]. Only two required walking aids; in both cases, walking aids were required to be a cause of chronic spine problems and not because of problems related to the hip. Li, et al., mentioned 22/24 of hip cases walked independently without any support [28]. Overall, the score was excellent in 12 patients and good in 10 patients, where Harris Hip Score was increased from mean pre-op HSS of 30.8± 9.7, to mean postop HSS of 90.2±4.2. Sharkey, et al., mentioned 4/13 complained of groin pain (2 had fractures identified intraoperatively and 2 were identified in the postoperative period), 1 died in the early postoperative period due to unrelated causes, and 1 had the postoperative infection for which resection arthroplasty was performed [27]. Three studies did not discuss the clinical outcome at the final follow-up [24,25,31]. Haidukewych, et al., mentioned that all fractures were united and all fractures had evidence of osseous ingrowth without component migration, 1 case had a well-fixed acetabular component for which he underwent revision [26]. Hasegawa, et al., mentioned bony ingrowth fixation in all cases [24]. Li, et al., mentioned excellent radiological outcomes with no loosening, osteolysis or migration of acetabular and femoral components and fractures were united in all cases as evidenced by X-rays [28]. Sharkey, et al., mentioned that there was radiographic evidence of healing in 10 patients (Table 3) [27].

Rehabilitation Protocol

Three studies discussed the modification in post-operative rehabilitation protocol [24,27,28]. Hasegawa, et al., mentioned that patients with occult fractures were kept on toe touch weight-bearing exercises for 6-8 and 2 patients with periprosthetic acetabular fractures were kept for non-weight bearing for 3 weeks [24]. Li, et al., mentioned that 5 patients avoided weight bearing for 4 weeks, and rest weight bearing as tolerated after surgery [28]. Sharkey, et al., mentioned that 10% weight-bearing for patients when the fracture was identified intraoperatively and in two patients non-weight bearing mobilization for 6 and 8 weeks was advised (Table 3) [27].

Femur Fractures

Patient Characteristics: Among the studies reporting intraoperative femur fracture during primary total hip arthroplasty [3,5-9,11,13,15-17,19-23]. One was a prospective study and the rest were retrospective studies [14]. Overall, the total number of intra-operative femur fracture was 595. The total number of patients enrolled in 16 studies was 21423, out of which 595 had femur fractures, with an overall incidence of 2.7%. 13 studies differentiate the sex of the study population, on 5259 patients of 16 studies. But only four studies mentioned the sex of patients in terms of intra-operative femur fracture where out of 195 patients, 79 were male and the rest were female, with Male: Female ratio of 1:1.46. Five studies mentioned the follow-up duration with a mean follow-up of 43 months (12-90 months) (Table 4) [5,7,11,15,16,21,23].

Preoperative Assessment

11 studies mentioned the pre-operative diagnosis for which the patient had undergone THR on 6202 hips [6-9,13,15-17,20-23]. Osteoarthritis was the cause of THR in 62.67% (n=3894), Developmental dysplasia of the hip in 17.76% (n=1102), Avascular necrosis of the femoral head in 13.09% (n=812) and post-traumatic arthritis in 6.35% (n=394) (Table 4).

Procedure and Approach

13 studies mentioned the type of procedure performed on 18025 hips with 687 fractures that had undergone the Uncemented THR. Rest six studies didn't mention the type of THR done. The approach used was mentioned by 10 studies where, anterolateral approach was performed in 11.54% (n=86) fracture cases, the direct anterior approach in 36.1% (n=269) fracture cases, the direct lateral in 32.21% (n=240 cases), and posterolateral in 42.5% (n=317) fracture cases (Table 5).

Location of Fracture

Three studies classified according to Mallory classification on 113 fracture cases, where Mallory type 1 was found in 68.14%

(n=77) cases, and 11.5% (n=13) fractures were type II, 4.42% (n= 5) fractures type III and 15.92% (n=18) type IV fractures (Table 5) [9,13,14].

Time of Occurrence and Diagnosis

14 studies mentioned intraoperative fractures at 88.41% (n=618), and 2 studies mentioned that the fractures were diagnosed in immediate post-operative periods in 17 patients [3,5-7-9,11,13,15-17,19-21-23]. Regarding the diagnosis of fractures, 21.26% (n=171) fractures were diagnosed clinically, whereas 64.80% (n=521) fractures were diagnosed radiographically and 13.93% (n=112) fractures were diagnosed by CT scan (Table 5).

Method of Management and Revision Surgery

Only 12 studies discussed the management of fractures where encirclage with Cerclage wire/band was done in 57.24% (n=316) fractures, revision surgery was performed in 2.89% (n=16), Bone graft was done in 0.3% (n=2), Circlage wire with long stem was done in 0.5% (n=3), non-operatively managed in 1.08% (n=6), and the treatment method was not discussed in 22.46% (n=124) fractures. Overall, the most common method of management done was encircling with cerclage wire or band.

A total of 5 studies mentioned revision surgeries in the post-operative period. Haidukewych, et al., mentioned one patient required revision [26]. Cohen, et al., mentioned just two patients (0.4%) in this series where the IFF changed management, requiring a revision femoral stem [16]. Miettinen, et al., mentioned 12 underwent revision surgeries [21]. Tamaki, et al., mentioned that stem revisions were noted after the use of a stem with a short tapered-wedge design that was inserted through the direct anterior approach (Table 6) [8].

Clinico-Radiological Outcome

Berend, et al., found that HHS improved an average of 34 points [9]. Ferbert, et al., mentioned mean improvement in HHS was 35.3 [13]. Overall, there was an increase in HHS by 39.43 in the post-operative phase (Table 6).

Rehabilitation Protocol

Ferbert, et al., mentioned that Postoperative rehabilitation was started on the first day after surgery [13]. Full weight-bearing and both active and passive motion exercises of the involved joint were allowed on the first postoperative day. Miettinen, et al., mentioned that partial weight bearing was started in cases with intra-operative fractures which were not fixed with cable wires [21]. Timmer, et al., mentioned that patients with intra-operative fractures were treated with a weight-bearing restriction for 6 weeks, followed by limited weight-bearing the first 6 weeks after surgery [11]. The rest of the studies suggested the normal post-operative rehabilitation protocol with full weight bearing if the fracture was fixed intra-operatively and to manage with a non-weight bearing if the fracture was not fixed intra-operatively (Table 6).

Quality Assessment

The studies included in this review varied considerably with MINORS scores. Since all included studies are non-comparative study, the total score is of 16, the calculated score ranged from 7 to 13. The study had a score of 10 or more is considered as good quality, and includes 10 such articles, the rest of the papers have a score of less than 10 (Table 7).

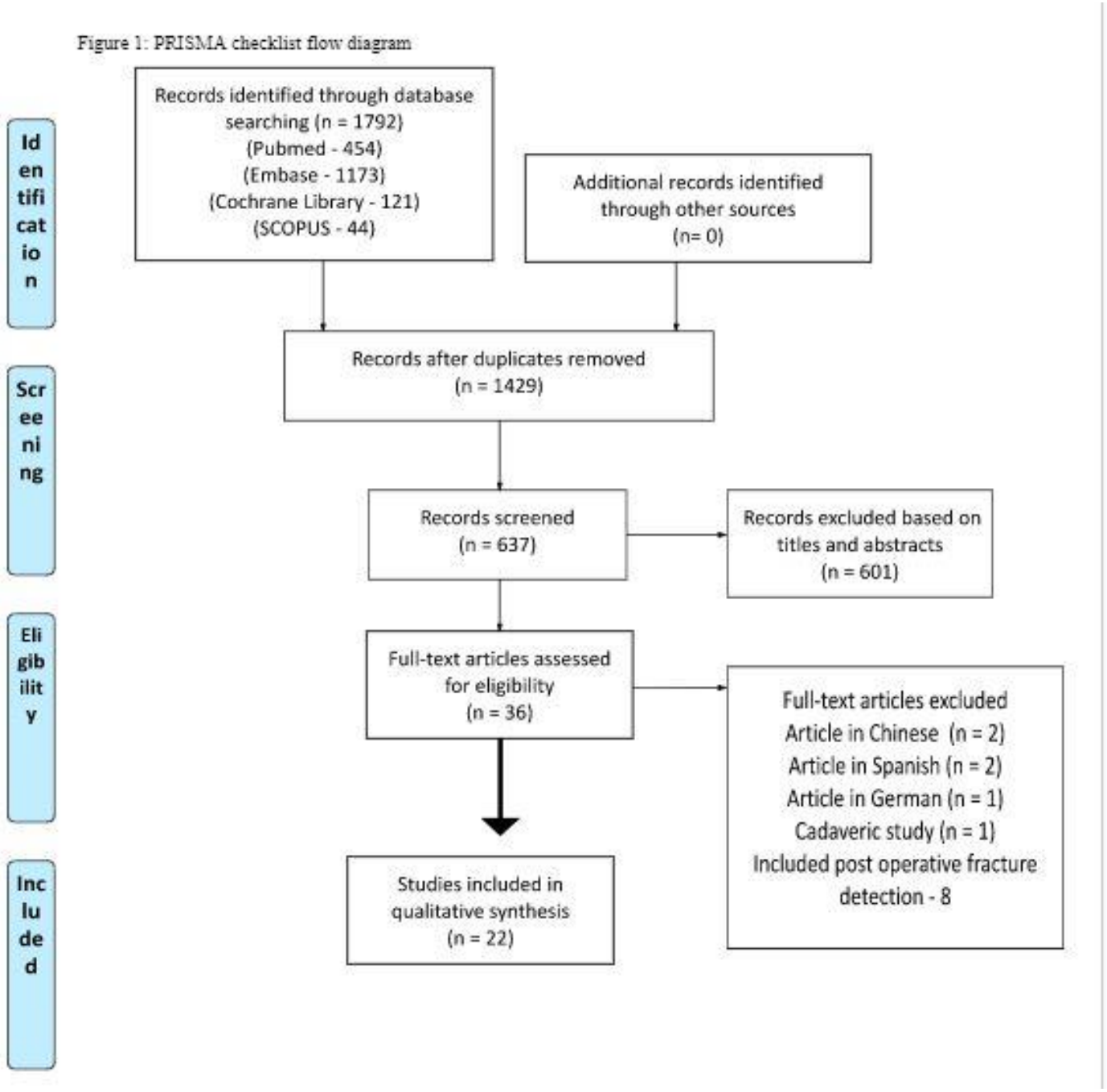

Figure 1: PRISMA Chart.

Author	Year	Country	Study	Mean Age	No of Patients	Gender M/F	Mean Follow Up (Months)	Preoperative Diagnosis
Dammerer, et al.,	2018	Austria	Retrospective	67.5 years (SD ± 11.6)	58	Female 36 Male 22	12 months (range 0-138)	Osteoarthritis 45 Fractures of femoral neck 5 Avascular necrosis of the femoral head 3 Osteoarthritis after hip Dysplasia 3 Fractures of the acetabulum 1 Pathological femoral neck fracture 1

Haidukewych, et al.,	2006	Minnesota	Retrospective	NR	7000	8 male, 13 female	44 months	Osteoarthritis (16), osteonecrosis (2), rheumatoid arthritis (1), post traumatic arthritis (1), femoral neck non-union (1)
Hasegawa, et al.,	2016	Japan	Retrospective	60 ± 11 years	406 (486 hips)	406 patients (102 males and 304 females; 486 hips)	58 ± 28 months	OA in 374 hips, rapidly 7estruct-tive coxarthropathy in 11 hips, rheumatoid arthritis in 20 hips, AVN in 69 hips, and other- 12 hips.
Li, et al.,	2020	China	Retrospective	53.8 ± 12.1 years	4888	NR	12 months	Adult avascular necrosis (11), ankylosing spondylitis (6), developmental dysplasia of the hip (5), osteoarthritis (2).
Laflamme, et al.,	2015	Canada	Retrospective	64 years	32	10 men and 22 women	36 months	NR
Sharkey, et al.,	1999	USA	Retrospective case series	62 years	13	11 women, 2 men	NR	Osteoarthritis (6), AVN (3), RA (2), Non-union NOF (1), congenital dislocation of hip (1)
NR - Not Reported; AVN - Avascular Necrosis of Femoral Head; NOF- Neck of Femur								

Table 1: Acetabular fracture, patient demographics including preoperative diagnosis and follow up.

Author	Procedure Performed	Approach	Number of Fractures / THA	Acetabulum Fracture	Femur Fracture	Location of Fracture	Displaced / Nondisplaced	Type of Implant Used	Time of Occurrence
Dammerer, et al.,	Cementless total hip arthroplasties	A lateral transgluteal and a direct-anterior approach	58	58	0	Acetabular fractures outside of the acetabulum but close to it (other locations; H5) = 45% (n = 26/ 58), at the superolateral wall (H3) =17% (n = 10/ 58), at the anterior wall of the acetabulum (H4) =16% (n = 9/58), in 10% (n = 6/58) each at the medial wall (H1)	NR	Acetabular cups Duraloc® 20 Trident® PSL 16 Trident® Hemispherical 13 Trilogy® 8 Allofit® 1	Post op
Haiduk Ewych, et al.,	17 Hybrid (uncemented acetabular, cemented femoral), 4 cementeless	18 anterolateral, 3 posterolateral	21	21	0	posterosuperior in twelve hips, directly posterior (involving the posterior wall) in six, medial in two, and anterosuperior in one.	NR	"Acetabular components twelve Implex components, one Trilogy com-ponent, seven PSL components, and one HG-II component. femoral components	In sixteen (76%) of the twenty-one hips, the fracture was noted during impaction of the real acetabular component; in three, it was noted

								nine Implex cemented components (Zimmer), four Centralign cemented components (Zimmer), three Implex hydroxyapatite-coated uncemented components (Zimmer), four Omnifit/ODC cemented components (Stryker Howmedica Osteonics), and one Omnifit hydroxyapatite-coated uncemented component (Stryker Howmedica Osteonics)."	during reaming; and in two, it was noted during initial hip dislocation.
Haseg Awa, et al.,	(Cementless or hybrid) THA	Posterolateral	41 hips (8.4%)	41	0	of the 41 occult fractures out of 486 hips, superolateral wall = 15 hips (15/41 hips; 37%), the medial wall =eight (eight of 41; 20%), anterior wall =seven (seven of 41; 17%), posterior wall = three (three of 41; 7%), and other locations =eight hips (eight of 41; 20%).	NR	out of 486 cups, 377 with press fit technique and additional screw fixation of which 32 showed occult fracture, 109 using pressfit only where occult fracture occured in 11. of total 43 occult fractures, peripheral self-locking cups in 30 hips, hemispheric cups in 11 hips, 2cases had periprosthetic fracture for which dome screw fixation for both with a peripheral self-locking cup and hemispheric cup each was used	Intra op

Li, et al.,	Uncemented THA	Posterolateral	24 hips	24(0.49%)	NR	directly posterior wall =11(45.8%) cases; anterior wall =5(20.8%) cases, medial wall =4(16.7%) cases, posterosuperior wall =1(4.2%) case, posteromedial wall =1(4.2%) case, posteromedial wall and posterior column =1(4.2%) case, anterior column =1(4.2%) case; 2/486 cases had periprosthetic fracture	NR	Combicup(4), Betacup(6), Pinnacle(13), T.O.P(1)	Intra op (17 during impaction of real acetabular component, 5 during inital hip dislocation and osteotomy, 1 during reaming
Laflamme, et al.,	Uncemented THA	NR	32	32	NR	According to judet and letournel classification, anterior wall(4), medial wall(7), posterior wall(9), posterior column(6), transverse(1), T-type(1)	2	Ucemented THA (monobloc pressfit 9, modular pressfit 23)	Intraoperative
Sharkey, et al.,	Uncemneted THA	NR	13	13	NR	NR	NR	Implex(2), Osteonics PSL(4), Zimmer HG1(1), Depuy Profile(2), Depuy Durolok(1), Biomet universal(1), Richard optiflix(1), Implex(1)	Intraoperative at time of impaction

Table 2: Acetabular fracture, characteristics of fracture and intra operative details.

Author	Method of Diagnosis: Clinical / Fluoroscopy	Method of Fracture Management	Revision Surgery	Clinical Outcome	HHS	Radiological Outcome	Post-operative Rehab Protocol
Dammerer, et al.,	CT scan	Revision surgery =8 patients (4 for postoperative infection at 2 week, 2m, 10 m, 23m), 2 for aseptic loosening (16m and 24m) and cup migration,2 for protrusion and obvious cup loosening)	8	NR	NR	NR	NR
Haiduk Ewych, et al.,	Clinically	Unstable acetabular component replaced by component with supplemental screw fixation - 4, no supplemental plates, lag screw or antiprotrusio device was needed in any patients.	One patient at 2 years postop	Assessing pain, walking ability, and the need for walking aids	NR	Union - all All fracture had evidence of osseous ingrowth without component migration, 1 case had well fixed acetabular component for which he underwent revision	NR
Haseg awa et al.,	CT	No additional treatment	Periprosthetic fracture fixed with dome screw with peripheral self-locking cup and hemispheric cup – 2	NR	NR	Bony ingrowth fixation in all cases	Occult fractures - toe touch weight bearing exercises for 6-8 weeks, Periprosthetic acetabular fractures (n=2) - NWB for 3 weeks
Li, et al.,	X-rays	Uncemented acetabular components and uncemented femoral components	2 plate fixations, 18 screw fixation, fracture labelled stable and managed conservatively – 4	Lost to follow up - 2, HHS excellent in 12, good in 10, trochanter split fixed with wire tensioner - 1, unhealed skin at 45 days - 1, hip dislocatio(POD 10) - 1 managed with open reduction	Mean pre-op= 30.8+/- 9.7, mean postop= 90.2 +/- 4.2	Excellent, no loosening, osteolysis or migration of acetabular and femoral components and fractures were united in all cases as evidenced by X-rays	5 patients avoided weight bearing - 4 weeks, and rest weight bearing as tolerated after surgery
Laflamme, et al.,	Ap and judet xrays and ct scan when available	None -16, screw only -11, posterior plate ORIF-5	8 patients	NR	NR	No cases of aseptic loosening, non-progressing acetabular lucencies in 6 patients,	NR
Sharkey, et al.,	X-rays	Extra screw in cups with spica cast (1), Extra screw (1), extra screw plus allograft (4), non-	2	4/13 - groin pain (2 had fracture identified intraoperatively and 2 were identified in postoperative	NR	Radiographic evidence of healing in 10 patients	10% weight bearing CDH patient was kept in hip spica, in two patients NWB mobilization for 6 and 8 weeks were

		weight bearing mobilization for 6 weeks (1), 8 weeks (1), none (5)		period), 1 death due to unrelated cause, 1 had postoperative infection - resection arthroplasty was performed			advised
NR - Not Reported; AVN - Avascular Necrosis of Femoral Head; NOF- Neck of Femur							

Table 3: Acetabular fracture, post op outcome.

Author	Year	Country	Study	Mean Age	No of patients	Gender- male (M); female (F)	Mean follow up (months)	Preoperative Diagnosis
Berend, et al.,	2004	Columbus	Retrospective	48.2 years (range, 32-77; SD, 11.3)	47	19 M / 28 F	7.5 years (range, 2.4 years-16 years; SD, 4.1 years)	Osteoarthritis 21 (42%) Congenital dysplasia 11 (22%) Avascular necrosis 8 (16%) Slipped capital femoral epiphysis or Legg-Calve´-Perthes 6 (12%) Rheumatoid arthritis 2 (4%) post-traumatic arthritis 2 (4%)
Berend, et al.,	2010	USA	Retrospective	NR	425 pt(457 THA)	NR	9 months (6 weeks to 31 months)	NR
Bo Liu, et al.,	2021	China	Retrospective	50.39 +/- 17.71	Patients without intraoperative periprosthetic femoral fractures (n = 1190) Patients with intraoperative periprosthetic femoral fractures (n = 62) Total (n = 1252)	Sex (n, [%]) 1.432* 0.231 Male 199 (16.72) 14 (22.58) 213 (17.01) Female 991 (83.28) 48 (77.42) 1039 (82.99) Age (years) 50.04 17.65 57.05 17.66 50.39 17.71	NR	NR
Mont, et al.,	1992	Baltimore USA	Retrospective	50.9 (25 to 80)	730		Two-year follow-up	Osteoarthritis 9 47 Rheumatoid arthritis 1 5 Avascular necrosis 3 16 post-traumatic 1 5 CDH 2 11 Old sepsis I 5 Ankylosing spondylitis 2
Hartford, et al.,	2016	Palo Alto, CA	Retrospective	66 y (range, 29-93)	500	314 Females 186 Males	3 Months	Diagnosis 468 Osteoarthritis 23 Avascular necrosis 3 Acute femoral neck fracture 2 Rheumatoid arthritis 2 Conversion of ORIF 1 DDH

								1 Legg-Calve-Perthes
Cohen, et al.,	2017	Province, Rhode Island	Retrospective	66.55 yearsThe average age of IFF patients was 70.67 years and in nonfracture patients was 66.00 years.	487 patients	(220 male and 267 females	NR	Diagnosis Osteoarthritis 419 Avascular necrosis 27 Rheumatoid arthritis 10 Dysplasia 19
Miettinen, et al.,	2016	Helsinki, Finland	Retrospective	Mean age at surgery (range) 60 (29-81)	2,913 patients,3,207 cementless THAs	1609-male,1304-female	4.2 (1.8-8.0) years	Diagnosis Primary osteoarthritis 70 (59) 93 (79) Developmental dysplasia of the hip 23 (20) 11 (9) Fracture a 7 (6) 6 (5) Rheumatoid arthritis 8 (7) 3 (2) Avascular necrosis 5 (4) 4 (3) Other 5 (4) 1 (1)
Colacchio, et al.,	2017	Boston, Massachusetts	Retrospective	65.8 years (range, 42-92 years)	46 hips	37 female and 9 males	3.25 years (range, 6 weeks to 12 years)	Forty-four patients had a preoperative diagnosis of osteoarthritis, 1 with avascular necrosis, and 1 with slipped capital femoral epiphyses
Ponzio, et al.,	2015	Pennsylvania	Retrospective	60.5 ± 13.4	Patients (Hips) 98 (102)	Female 68 Male 30	Not mentioned	Osteoarthritis 83 (81%) Avascular Necrosis 14 (13%) SCFE 2 (2%) Congenital Dysplasia 2 (2%) Rheumatoid Arthritis 1 (1%) Post-traumatic Arthritis 1 (1%)
Rüdiger, et al.,	2013	University of Zurich	Retrospective	(68 ± 9 years)	484	Male 38%	1 year	NA
Ran Zhao, et al.,	2016	Beijing, China	Nested case-control	57.38±12.60 years	904 primary cementless THA (769 patients)	366 male patients (439 procedures) and 403 female patients (465 procedures)	NR	Developmental dysplasia of the hip 232 11 4.52% Avascular necrosis 369 6 1.60% Femoral head/neck fracture 145 3 2.03% Idiopathic 42 2 4.55% Rheumatoid arthritis 61 2 3.17% Posttraumatic 31 0 0.00%
Timmer, et al.,	2018	The Netherlands	cohort study	64.0 (8.8)	Total (n=800)	Male 315	NR	NR

						(39.4%) female 485(60.6%)		
Tootsi, et al.,	2020	University of Tartu, Estonia	Retrospective	56 years (14-77 years)	222 THA	Male/female (n) 112/110	17 months (3-34 months)	Primary osteoarthritis 200 (90.1) Femoral neck fracture 2 (0.9) Posttraumatic osteoarthritis 5 (2.3) Legg-Calve-Perthes 3 (1.4) DDH 5 (2.3) Idiopathic AVN 6 (2.7) Revision (MoM acetabular component loosening) 1 (0,5)
Fleischman, et al..,	2017	Philadelphia, Pennsylvania	Retrospective	62.6 (12.4) first gen 63.5 (10.6) second gen	First Generation (n = 3126) Second Generation (n = 3347)	Male gender, % 47.6% (1st gen) 49.7% (2nd gen)	NR	NR
Tamaki, et al.,	2017	Chiba, Japan	Retrospective	63.6 ± 9.8	686 patients (851 hips)	Male, 141 hips; female, 710 hips	3, 6, and 12 weeks, and then, annual follow-up examinations were performed	Osteoarthritis of the hip in 811 hips (95%; primary osteoarthritis in 117 hips [14%], secondary osteoarthritis associated with hip dysplasia in 676 hips [79%], and secondary osteoarthritis associated with other causes in 18 hips [2%]) and avascular necrosis of the femoral head in 40 hips (5%). Among 851 hips, 75 (8%)
Sun, et al.,	2021	Suining, China	Retrospective	63.50 (51.00, 72.00)	261 patients (273 hips)	Male 140/Female 133	NR	osteonecrosis of the femoral head (ONFH, Ficat III, IV), osteoarthritis (OA), developmental dysplasia of the hip (DDH, Crowe I, II), femoral neck fracture (FNF), osteo-necrosis of the femoral head after

								cannulated screw fix-ation of femoral neck fracture (internal fixation in the body, 12 patients), coxa plana, ankylosing spondylitis, and rheumatoid Arthritis (RA)
Ferbert, et al.,	2020	Heidelberg, Germany	Retrospective	61 years (SD 11.8, range 31-85)	6508 patients		5.6 years (range 2-11.8 years) for the fracture group and 6 years (range 4.1-8.3 years) for the control group	Mild dysplastic OA (n = 21), primary OA (n = 20), avascular necrosis of the hip (n = 7) and femoral neck fracture (n = 2)
NR - Not Reported								

Table 4: Femur fracture, patient demographics.

Author	Procedure Performed	Approach	Number of Fractures / THA	Acetabulum Fracture	Femur Fracture	Location of Fracture	Displaced / Nondisplaced	Type of Implant Used	Time of Occurrence
Berend, et al.,	THA	Anterolateral abductor split approach	50	0	50	43 type 1 mallory, 7 type 2 mallory	Undisplaced	Mallory-Head Porous femoral component	Intraop
Berend, et al.,	THA	Modified smith Peterson	2	0	2	Mallory type 2	Undisplaced	Monoblock tapered wedge design=439, modular tapered wedge design = 18	Intraop
Bo Liu, et al.,	Uncemented THA	Approach (n, [%]) 0.010† 0.919 Posterior 1117 (93.87) 58 (93.55) 1175 (93.85) Anterior 73 (6.13)	62	0	NR	62	NR	NR	Intraop
Hartford, et al.,	Cementless total hip arthroplasties	Direct anterior approach	Twenty-three hips (4.6%) incurred fractures, 13 (2.6%) intraoperative and 10 (2.0%) post-operative	0	23	NR	NR	Depuy Corail (Warsaw, IN) 241 Zimmer ML Taper (Warsaw, IN) 250 Zimmer Fitmore (Warsaw, IN) 4 Depuy Triloc (Warsaw, IN) 3 Depuy Summit	Thirteen fractures (2.6%) were intraoperative and 10 (2.0%) were postoperative

								(Warsaw, IN) 1 Smith Nephew Richards Anthrology (Memphis, TN) 1	
Cohen, et al.,	Cementless total hip arthroplasties	Direct Anterior Approach	12	0	12(8M/4F)	Dorr classification A 109 B 284 C 82	NR	Stem DAA Without Fracture Table- Stem Tri-Lock Corail Summit	Intra op
Miettinen, et al.,	Cementless total hip arthroplasty	Posterolateral or direct lateral (Hardinge) surgical approach	118	0	118 Male 50 (42) Female 68 (58)	Dorr classification n (%) Type A 55 Type B 42 Type C 13 Impossible to measure 8	NR	Conserve Profemur TL (Wright Medi-cal Technology, Arlington, TN), M/L Taper (Zimmer, Warsaw, IN), and Corail (DePuy Orthopaedics, Warsaw, IN)); fit and fill (e.g. Bi-Metric (Biomet, Warsaw, IN) and Synergy (Smith and Nephew, Memphis, TN); and other (e.g. Reach (Biomet) and Biomet CDH)	Intra op
Colacchio, et al.,	Cementless THA	Posterior approach	(46 hips)	0	(46 hips) 9M/37F	Dorr A 18/41 (43.9%) Dorr B 19/41 (46.3%) Dorr C 4/41 (9.8%)	Non displaced	Accolade I and Accolade II	Intra op
Ponzio, et al.,	Cementless Total Hip Arthroplasty	Anterolateral approach	102	0	102	Dorr A (36%) Dorr B (50%) Dorr C (14%)	Nondisplaced or minimally displaced incomplete linear discontinuity	Accolade and Tri-Lock	Intra op (During insertion of the femoral stem)
Rüdiger, et al.,	Primary THA	Direct anterior approach	13	0	13	5 simple metaphyseal (1 %) and 8 greater trochanter (1.7	NR	Not mentioned	Intra op

						%) fractures			
Ran Zhao, et al.,	Primary cementless THA	Anterolateral 316 4.82% Posterolateral 564 1.40%	24 (2.65%)	0	24	Type A 453 2.58% Type B 345 2.27% Type C 82 4.65%	Non-displaced incomplete linear fractures	Cementless THA, 805 were performed with Synergy stems and another 99 were performed with Co-rail stems	Intra op
Timmer, et al.,	Cementless CLS Spotorno stem	Posterolateral approach	17 (2.1%)	0	17 (2.1%)	Calcar fractures	NR	Cementless CLS Spotorno stem	Intra op
Tootsi, et al.,	cementless THA	Direct lateral 116 (52) Posterolateral 106 (48)	12	1	11	NR	1 undisplaced acetabular fracture	SP-CL® implant.	intra op
Fleischman, et al.,	Cementless THA	Direct lateral (modified Hardinge) [22], direct anterior (modified Smith-Peterson) [23], or anterolateral (Watson-Jones) [24] approach	6 of 3126 cases) for first-generation stems 6 of 3347 cases) for second-generation stems	0	6 of 3126 cases) for first-generation stems 6 of 3347 cases) for second-generation stems	Femur Fracture	Fractures not identified and treated intraoperatively can later become displaced. fractures identified and addressed intraoperatively and fractures occurring in the early 30-day postoperative period that could represent nondisplaced intraoperative fractures	A first-generation (Accolade TMZF, Stryker Orthopaedics, Mahwah, NJ) or second-generation (Accolade II, Stryker Orthopaedics, Mahwah, NJ) cementless, proximally coated, double tapered wedge femoral stem	Intra op
Tamaki, et al.,	Cementless THA	Direct anterior approach	17	0	17	Periprosthetic Femoral Fractures DORR B -8, DORR C-2	Un-displaced	Cementless implants	10 intraoperative (1.2%) and 7 postoperative (0.8%) fractures
Sun, et al.,	Primary THA	Direct anterior approach	34 cases (35 hips) of femoral fracture	0	34 cases (35 hips) of femoral fracture	Femoral Fractures	NR	NR	34 cases (35 hips) of femoral fracture
Ferbert, et al.,	Primary uncemented THA	Direct anterior approach	50 patients (0.9%)	0	50 patients (0.9%)	Modified Mallory classification21 patients sustained a type 1 fracture, 6 patients type 2 fractures, 5 patients type 3	Femoral fractures	CLS stem (Zimmer, Warsaw, IN, USA) n = 19, Wagner cone stem (Zimmer, Warsaw, IN, USA) n = 12,	59 patients (0.9%)

						and 18 type 4 fractures, respectively.		Fitmore stem (Zimmer, Warsaw, IN, USA) n = 7, Profemur stem (Wright Medical, Arlington, TN, USA) n = 2 and MRP stem (Peter Brehm, Erlangen, Germany) n = 2.	
NR - Not Reported									

Table 5: Femur fracture, characteristics of fracture and intra operative details.

Author	Method of Diagnosis: Clinical / Fluoroscopy	Method of Fracture Management	Revision Surgery	Clinical Outcome	HHS	Radiological Outcome	Post-operative Rehab Protocol
Berend, et al.,	Clinically	Cerclaged with a single wire or cable	Nil	Hips with moderate anterior thigh pain 2(4%); One stem subsided 17 mm,requiring the use of a shoe lift.	Improved an average of 34 points	NR	NR
Berend, et al.,	Clinically	Single cerclage cable	Nil	None had hip related symptoms	NR	No subsidence	Patient walked 30 feet on POD-0 with assistance and supervision of physical therapist, using a walker or crutches. Weight-bearing as tolerated allowed for all patients
Bo Liu, et al.,	Clinically	None	NR	NR	NR	In the fracture group, there was a significantly higher retained femoral neck length than in the non-fracture group (11.68 4.33 vs 11.38 3.16)	NR

Hartford, et al.,		Calcar (n 1⁄4 6) Cerclage wire (n 1⁄4 6) Calcar (n 1⁄4 8) Return to operating room for ORIFdcerclage wire (n = 5), Treated nonoperatively (n = 3) Trochanteric (n = 5) Figure-of-eight cerclage wire (n = 2) Nonoperative (n =3) Trochanteric (n = 2) Return to operating room for ORIF, figure-of-eight cerclage wire (n = 1), Treated nonoperatively (n = 1) Canal perforation (n = 2) Cerclage wire (n = 2)		The risk of fracture using the direct anterior approach is higher	NR	NR	NR
Cohen, et al.,	AP and lateral fluoroscopic views intraoperatively	Just 2 patients (0.4%) in this series where the IFF changed management requiring a revision femoral stem		Then other approaches to the hip	NR	NR	NR
Miettinen, et al.,	Radiographs	Fixation with cables (n = 114) or partial weight bearing with-out cables (n = 4)	12 of the 118 undergone revision sx	Dorr type B = No higher risk of intraoperative calcar fracture than Dorr type A (OR = 1.5, CI: 0.76-2.9). There was a higher risk of calcar fracture if the proximal femur was Dorr type C rather than Dorr type A (OR = 6.5, CI: 1.3-33)	NR	NR	NR
Colacchio, et al.,	Radiographs	Prophylacti-cally stabilized with cerclage wiring following standard surgical technique	None	Accolade II is better than Accolade TMZX	NR	NR	NR

Ponzio, et al.,	Radiographs	Fracture fixation involved removal of the prosthesis, cerclage of the proximal femur with a cable above the level of the lesser trochanter, impaction of the femoral component then final tightening of the cable and crimping of the fixation clip	0	Accolade Tri-Lock P-value Gender (Female/Male) 23/11 45/19 P = 0.82 Side (Right/Left) 25/11 32/34 P = 0.06 Age (Years) 62.5 ± 13.9 60.2 ± 12.2 P = 0.82 BMI 30.5 ± 7.6 28.5 ± 5.7 P = 0.18 Length of Stay (Days) 3.3 ± 1.0 3.4 ± 1.5 P = 0.99 Female gender (OR = 1.96; 95% CI 1.19-3.23; P = 0.008) and smaller stem size (OR = 1.64; 95% CI 1.04-2.63; P = 0.03) predicted increased odds of fracture	NR	NR	NR
Rüdiger, et al.,	Radiographs	NA	No patient required revisions	Trochanteric fractures do heal without primary fixation. Metaphyseal fractures heal well if immediately stabilized with a cerclage	NR	Plain X-rays preoperatively, plain X-rays in recovery and at 3 months	NR
Ran Zhao, et al.,	C-arm radiograph	Not mentioned	No patient required revisions	NR	NR	NR	NR
Timmer, et al.,	Post op radiographs	One calcar fracture was identifed on the post-operative radiograph; this patient was treated with a weight bearing restriction for 6 weeks. Two cases intraopera-tively converted to a cemented stem because of a calcar frac-ture. The remaining calcar fractures (n=13) success-fully treated with one or two cerclage wires	NR	CLS cementless Spotorno	NR	NR	Limited weight bearing the frst 6 weeks after surgery

Tootsi, et al.,	Pre- and postop-erative radiographs	Subtrochanteric (lateral cortex) 2 Conservative Greater trochanter fracture 2 Cerclage wire Calcar 7 Titanium band (3) Cerclage wire (2) Conservative (2) 11 (5.0%) intraoperative femoral fractures (IFF), of which 7 treated with cerclage wire or titanium band during the operation while the other fractures were treated conservatively	No patient required revisions	SP-CL® implant	NR	Proximal femoral morphology assessed using canal fare index (CFI), cortical index, and canal-calcar ratio CFI<3 was classifed as stovepipe, CFI 3-4.7 as normal, and CFI>4.7 as champagne fute-shaped canal. In addition, the angle of the femoral component and leg length discrepancy were measured from the postoperative radiograph. radiological (radiolucent zones and migration of the implant)	(Complaints, range of motion, and satisfaction)
Fleischman, et al.,	Post op radiographs	Nearly all intraoperative fractures (61 of 64 cases) were repaired with cerclage cabling, and the remaining 3 cases underwent conversion to a long femoral stem	NR	a first-generation (Accolade TMZF, Stryker Orthopaedics, Mahwah, NJ) or second-generation (Accolade II, Stryker Orthopaedics, Mahwah, NJ) cementless, proximally coated, double tapered wedge femoral stem	NR	NR	NR
Tamaki, et al.,	Clinically and post op radiographs	Wiring during the primary surgery	Stem revision after the use of a stem with a short tapered-wedge design inserted through direct anterior approach	The stem design affects the risk of periprosthetic femoral fractures	NR	NR	Rehabilitation started on the first day after surgery. Full weight-bearing and both active and passive motion exercises of the involved joint were allowed on the first post-operative day
Sun, et al.,	Post op radiographs	NR	NR	Osteoporosis and a shorter ASIS-GTD = independent risk	NR	NR	NR

				factors for femoral fracture			
Ferbert, et al.,	Post op radiographs	NR	No stem revisions in the fracture group and 1 stem revision in the control group	Stem revision, Harris Hip Score improvement, pain scale improvement, WOMAC, Tegner Score, UCLA, SF-36, forgotten joint score and patient satisfaction	Mean improvement in Harris hip score = 35.3 and 44.8 respectively. in cases and control groups	Assessed for bone union, radiolucency, signs of stem subsidence and cerclage wire displacement. All patients demonstrated consolidated fractures at final radiological follow-up	NR
NR - Not Reported; HHS - Harris Hip Score							

Table 6: Femur fracture, post op outcome.

SL No	Article Name	A Clearly Stated Aim	Inclusion of Consecutive Patients	Prospective Collection of Data	Endpoints Appropriate to The Aim of The Study	Unbiased Assessment of The Study Endpoint	Follow-Up Period Appropriate to The Aim of The Study	Loss To Follow Up Less Than 5%	Prospective Calculation of The Study Size	Total Minor Score
1	Liu, et al.,	2	2	0	2	1	2	0	0	9
2	Hartford, et al.,	2	2	0	2	1	1	1	0	9
3	Berend, et al.,	2	1	0	2	1	2	0	0	8
4	Cohen, et al.,	2	1	0	2	1	0	1	0	7
5	Miettinen, et al.,	2	2	0	2	2	2	1	0	11
6	Colacchio et al.,	2	2	0	2	1	2	1	0	10
7	Ponzio, et al.,	2	2	0	2	2	0	1	0	9
8	Rüdiger, et al.,	2	2	0	2	1	2	0	0	9
9	Berend, et al.,	2	2	0	2	1	2	0	0	9
10	Ran Zhao, et al.,	2	2	1	2	2	2	0	0	11
11	Timmer, et al.,	2	2	2	2	1	2	0	2	13
12	Tootsi, et al.,	2	2	1	2	2	2	0	0	11
13	Fleischmanet, al.,	2	2	0	2	1	2	0	0	9
14	Tamaki, et al.,	2	2	0	2	1	2	1	0	10
15	Sun, et al.,	2	2	0	2	1	0	1	0	8
16	Ferbert, et al.,	2	2	0	2	1	2	0	1	10
17	Haidukewych. et al.,	2	2	0	2	1	2	1	0	10
18	Hasegawa, et al.,	2	2	0	2	1	2	1	0	10
19	Li, et al.,	2	2	0	2	1	1	1	0	9
20	Aflamme, et al..	2	2	0	2	1	1	1	0	9
21	Sharkey, et al.,	2	2	0	2	2	0	0	0	8
22	Dammerer, et al.,	2	2	0	2	1	2	1	0	10

Table 7: MINORs scoring.

Discussion

Intra-operative periprosthetic fracture during primary total hip arthroplasty is a relatively common entity with the femoral side being involved more than the acetabular side and there are some studies existing in literature on this topic [32]. We conducted a systematic review of the available literature to define the incidence, risk factors, time of occurrence of the fracture during surgery, characteristics of the fractures, management options and outcomes. We have also identified precautions to be taken to prevent these fractures. No study in literature has defined the amount of impacting force as a determinant to the occurrence of

intraoperative fracture. However, from our common shared experience we know that hammering the trial or final acetabular component of a smaller size than the rim fit may lead to acetabular fracture. Similarly, the femoral fractures occur when the trial of larger size is hammered into a smaller canal.

Acetabular Fractures

We identified incidences ranging from 0.3% to 8.4% but this may be underestimated as some of the intraoperative fractures may go unnoticed, and minimally displaced fractures not requiring any intervention may not be reported. The majority of the authors in this review reported incidence below 1% [25-28,31]. An overall incidence of 0.49% was noted (86/12294) in patients with a mean age of 61.46 years at a mean follow-up of 32.4 months (12-58 months). Two studies performed hybrid THR in the majority (58/62) of such patients however overall, 69.31% (131/189) of cases were operated by the uncemented THR technique. The maximum number of such cases were being operated through the posterolateral / trans-gluteal approaches and the minimum cases by the anterolateral approach. However, it remains the surgeon's preference to pursue these approaches and the intraoperative fracture was not related to the approach used.

Hasegawa, et al., classification was used most commonly to classify the location of the fracture and the most common site encountered was the superolateral wall (26.38%) whilst the medial wall was noted to be the least common site [24]. Most studies described that these fractures can and must be picked intraoperatively. However, it was virtually impossible to diagnose the exact timing of the fracture and invariably the fracture was noted at the time of impaction of the final acetabular component. It is worth noting that one must be suspicious about the occurrence of such fractures and must rule them out using X-rays and CT scans wherever available apart from clinically.

The management of these fractures depends on the stability of the final acetabular component. A well-fixed and stable component warrants no further intraoperative intervention. However, some authors have suggested additional screws or replacing the component allowing supplemental screw fixation. Sharkey, et al., has also suggested the use of screw plus allograft as a supplement to fixation [27]. Two authors have suggested plate fixation in certain cases [26,30]. However, no use of an antiprotrusio device was found necessary by any of the authors. Post-operative rehabilitation protocol is modified in all such cases as a norm.

Revisions needed to be performed in 11.11% of cases. However, these revisions were attributable to causes not modified by the intraoperative fractures such as postoperative infection, aseptic loosening, cup migration, protrusion/ obvious cup loosening and periprosthetic fractures.

The final clinical outcomes were described by three studies. 38/42 hip cases walked independently without any support. Two patients had to use walking aids owing to chronic spine etiologies. Harris Hip Score was found to improve from mean pre-op HSS of 30.8± 9.7 to mean postop HSS of 90.2±4.2.

The final radiological outcomes were described by five studies. It is noteworthy that all the authors independently concluded that all the fractures had radiological evidence of osseous ingrowth and fixation in all cases. The rehabilitation protocol should be modified keeping in mind the healing of the fracture. Non-weight bearing for 3-4 weeks followed by toe touch or weight bearing as tolerated in occult or obvious fractures respectively.

Femur Fractures

595 intraoperative fractures were noted in 16 studies [3,5-9,11,13,15-17,19-23]. Total patients were documented as 21423 across 16 studies in which the incidence was seen to be 2.7%. Four studies found that the incidence of male: female was 1:1.46. Mean follow-up was found to be 43 months (12-90 months) in seven studies. The pre-operative diagnosis was found to be osteoarthritis most commonly in 62.67%, DDH hip in 17.76%, AVN hip in 13.09% and post-traumatic arthritis in 6.35%.

Procedure and Approach

687 fractures were noted in 23025 hips in 18 studies accounting for uncemented THR. Femoral fractures were noted most commonly in posterolateral approach followed by direct anterior and direct lateral approach.

Fracture Location

Three studies documented the location as per the Mallory classification where type I was found most commonly and type II was found least commonly.

Time of Occurrence and Diagnosis

The majority of the fractures were diagnosed intraoperatively (88.4%) whilst the rest were diagnosed postoperatively (11.5%). Diagnosis in most cases was radiographic (64.8%) while the rest of the cases were diagnosed clinically or by CT scan.

Method of Management and Revision Surgery

12 studies discussed the management of these fractures ranging from nonoperative management to revision surgery including encircling with cerclage wire/band which was the most common method of management (57.2%) to bone grafting and cerclage wire with replacement with a long stem [8,9,11-13,16,17,19,21-23]. Management was not mentioned in 22.46% of these studies suggesting that management techniques may vary beyond the ones mentioned and may be devised on the table as per the fracture timing, location, pattern and availability of implants.

Revision surgeries were needed in very few cases and out of these cases short tapered-wedge design that was inserted through the direct anterior approach was commonly found.

Clinico-Radiological Outcome

Outcomes were recorded in terms of Harris Hip score and were found to improve from 34 points to 49 points in various studies. The mean improvement was found to be 39.43 in the postoperative period.

Rehabilitation Protocol

It is noteworthy that the studies conclude a full weight-bearing mobilization be allowed in cases where satisfactory intraoperative fixation has been achieved and a non-weight-bearing protocol be followed for 6 weeks in patients where an intraoperative fixation has not been achieved.

The current review to the best of our knowledge is only the review to assess intra-operative acetabulum and proximal femur fracture in total hip arthroplasty encompassing a wide variety of studies with a representative cumulative sample. But this study has its limitations, first longer follow up studies are required for actual assessment of the outcome. Secondly only one study included was prospective study, majority of the articles are retrospective, thirdly there were no comparative study exists where compares conservative management or augmentation method and also in augmentation method there is no comparative study on the available method of augmentation. Lastly, the protocol for the review was not pre-registered for systematic review.

Conclusion

Intra-operative fractures during primary total hip arthroplasty are not very rare with higher risk associated with factors contributing to poor bone quality such as osteoporosis, rheumatoid arthritis, advanced age, female gender, chronic steroid use, metabolic bone disorders etc. Patients with such risk factors warrant careful pre-operative planning with a full medical history, evaluation of bone stock and maintaining inventory of appropriate instruments and implants. The inaccurate technique of exposure, bone preparation and trialing, final femoral implant placement, reaming of the acetabulum and impaction of the acetabular component are associated with a higher incidence of these fractures. A plethora of management options has been utilized according to surgeon preference and the fracture pattern as well as location. Standard principles of fracture fixation and arthroplasty should be followed to achieve stable internal fixation and any unstable fracture site should be bypassed with the utilization of long-stemmed components. A satisfactory radiographic and functional outcome can be expected with appropriate treatment.

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Conflict of Interest

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Author Contributions

SA: Planning of study, data management, writing and revising the manuscript; TG: Planning of study, data management; AR: Planning of study, writing and revising the manuscript; BBN: Data management, manuscript preparation; DP: Data management, manuscript preparation; AKC: Planning of study, revising the manuscript; BSR: Planning of study, revising the manuscript; RBK: Planning of study, writing and revising the manuscript.

Ethical Approval:

This study was performed in line with the principles of the Declaration of Helsinki. The intuitional ethical committee has provision that ethical clearance is not required for review articles and for paper publication for the same.

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