Subchondral insufficiency fractures of the femoral head: systematic review of diagnosis, treatment and outcomes

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Submitted 23 May 2019; Revised 16 September 2019; revised version accepted 3 October 2019

ABSTRACT  
Subchondral insufficiency fractures of the femoral head (SIFFH) are a cause of femoral head collapse leading to degenerative hip disease. SIFFH is often mistaken for osteonecrosis due to similar clinical and radiographic features. These similarities often lead to missed or delayed diagnosis which can affect the treatment options, including hip preservation in young patient populations. A systematic review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. All related peer-reviewed publications from January 1999 to January 2019 were reviewed using the following databases: Medline, EMBASE, Scopus and Web of Science. The systematic review identified 54 articles, encompassing 504 hips, diagnosed with SIFFH. One hundred and seventy-six (35%) males and 306 (63%) females were included, with a mean age of 53.6 ± 17.5 years and mean body mass index of 23.4 ± 4.0 kg/m². Mean follow-up was 23.4 ± 15.9 months. Treatment decisions were 256 (55%) non-operative, 157 (34%) total hip arthroplasty (THA), 24 (5%) transtrochanteric anterior rotational osteotomy, 9 (2%) hip arthroscopy, 7 (2%) hip resurfacing, 3 (1%) bone grafting, 3 (1%) hemiarthroplasty and 1 (1%) tantalum rod insertion. Overall, 35% of SIFFH hips were converted to THA at latest follow-up. A majority of SIFFH patients had symptom resolution with non-operative management. Failure most often resulted in THA. In younger patients, hip preservation techniques have shown promising early results and should be considered as an alternative.

INTRODUCTION  
Subchondral insufficiency fractures of the femoral head (SIFFH) are a cause of femoral head collapse which can lead to degeneration of the joint. SIFFH was first reported as a distinct disease in 1996 [1]. More recently, SIFFH has been shown to be histopathologically different from osteonecrosis, another cause of femoral head collapse [2, 3]. Because of the similarities clinically and radiologically between SIFFH and osteonecrosis of the femoral head, they are difficult to distinguish; however, their etiologies are different. Bone fragility has been purported as an important cause of SIFFH and the typical patient described is an elderly female [4–7]. In addition to causing hip degeneration, SIFFH has been also been implicated as a potential cause of rapidly destructive arthritis [7–9], and its role in hip pain and degeneration in younger patient populations is of clinical interest.

There is a wide range in presentation of SIFFH, which impacts the treatment decisions. While SIFFH is typically described in older patients, it has been seen in younger patients, specifically military recruits, transplant patients and patients with tumor osteomalacia [10–12]. Depending...
on the extent of the fracture and collapse, various treatments for SIFFH have been reported, including non-operative management, total hip arthroplasty (THA), hip arthroscopy, transtrochanteric anterior rotational osteotomy (TARO) and coring [13–16]. Because of this variability, there is little consensus as to the appropriate treatment option for a patient with SIFFH.

The purpose of our study is to systematically review the literature to determine the demographics, diagnostic techniques and treatment options in SIFFH management. Based on prior literature, we hypothesized that SIFFH patients may be younger than previously reported. Accordingly, the use of joint preservation techniques may be more prevalent in younger patients given advances in surgical technique and the desire to preserve native anatomy.

**MATERIALS AND METHODS**

A systematic review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines and checklist [17]. All peer-reviewed publications related to SIFFH, published from January 1999 to January 2019, were identified. Two reviewers independently conducted the search in February 2019 using the following databases: Medline, EMBASE, Scopus and Web of Science. Each search included the following terms: subchondral AND insufficiency AND fracture AND femoral AND head.

Our inclusion criteria consisted of English language or articles with English translations, studies with patients’ gender and age with SIFFH and reporting of treatment of SIFFH. Exclusion criteria were non-English language studies, studies, studies without specific reporting on treatment of SIFFH and studies without specific reporting on how many SIFFH patients/hips were included.

Following the two independent authors (MAG, LTS) search of the previously stated databases, a total of 120 citations were identified. A consensus for any uncertainties was reached with the help of a third author (BM). Duplicate articles were excluded. The search process is shown in the flow diagram (Fig. 1). Title and abstracts were assessed for relevancy, and a total of 54 full-text articles were selected for further evaluation. References within each article were cross-referenced for inclusion to ensure that all studies available were identified.

Data collected from the studies was level of evidence, number of patients with SIFFH, mean age, mean body mass index (BMI), primary diagnosis imaging modality, treatment, purposed etiology, mean follow-up and outcome of SIFFH post-diagnosis. If means were not given, medians were used. For case reports with two or fewer patients, we reported the ages of cases separately. Our primary outcome of interest of SIFFH post-diagnosis was reported as conversion to THA at latest follow-up. SIFFH patient outcomes managed specifically with hip preservation techniques at index treatment point were recorded separately. Values were compared against the patient acceptable symptomatic state (PASS) reported by Chahal et al. [18].

Statistical analysis was utilized to calculate mean age, mean BMI, prevalence of bone marrow edema (BME) on magnetic resonance imaging (MRI), prevalence of treatment, etiology, mean follow-up and prevalence of outcome of SIFFH on diagnosis. When provided, these values were calculated using an unpaired Student’s t-test. Means and standard deviations were calculated from patient series if none were reported. All statistical analyses were performed using Microsoft Excel software (Version 16.16.17, Microsoft, Redmond, WA, USA).

**RESULTS**

Based on the PRISM guidelines, 54 full-text articles were selected for analysis (Fig. 1). Of the 13 excluded, six articles did not include treatment of SIFFH, three articles did not include SIFFH, two articles had SIF but not of the femoral head, one did not include demographic information and one did not have details on diagnosis.

Of the 54 articles included, 482 patients (504 hips) diagnosed with SIFFH included 176 (35%) males and 306 (63%) females. Mean age was $3.6 \pm 17.5$ years and mean
BMI was 23.4 ± 4.0 kg/m². The most common imaging modality (93%) used to diagnosis was MRI, with 9% using primarily X-ray or computed tomography (CT). On MRI, 88% (294) of SIFFH patients showed signs of BME. The mean follow-up was 23.4 ± 15.9 months.

Treatment decisions were: 256 (55%) non-operative, 157 (34%) THA, 24 (5%) TARO, 9 (2%) hip arthroscopy, 7 (2%) hip resurfacing, 3 (1%) bone grafting, 3 (1%) hemi-artroplasty and 1 (1%) tantalum rod insertion. The etiology of SIFFH patients was as follows: 24% (16) chronic steroid use, 24% (16) tumor osteomalacia, 10% (7) organ transplant, 7% (5) osteoporosis, 6% (4) radiation, 6% (4) overexertion, 6% (4) alcohol abuse, 3% (2) previous internal fixation, 3% (2) systemic lupus erythema, 1% (1) acetabular over-coverage, 1% (1) acetabular over-coverage, 1% (1) anorexia, 1% (1) alkaptonuria, 1% (1) dysplasia and inverted labrum, 1% (1) rapid destructive arthrosis, 1% (1) renal failure, 1% (1) Turner syndrome and 1% (1) adrenocorticotropic adenoma. Overall, 35% of SIFFH hips were converted to THA at latest follow-up. Full results are recorded in Table I. SIFFH patient outcomes managed specifically with hip preservation techniques at index treatment point are recorded in Table II.

DISCUSSION

The current study reviewed the available literature, and found SIFFH patients to be, on average, 54 years of age, female and low-normal to overweight BMI. MRI was the dominant mode of diagnosis. Most patients were treated non-operatively, with THA being the most common surgical intervention. SIFFH presents with acute hip pain and can be collapsed or stable on imaging. We found a relatively large percentage of patients eventually suffer a worsening of their disease and required surgical treatment. The exact cause of collapse and worsening of symptoms is not known and warrants further research.

SIFFH is a cause of acute hip pain in the elderly; however, SIFFH must be included in the differential diagnosis in younger patients. Yamamoto and Bullough [2, 13, 19] described SIFFH patients to be an elderly female with a high BMI, and, due to the prevalence of osteoporosis, this characterization has continued throughout the literature, even in recently published studies. We found SIFFH to be shown in a wide variety of adult patients. On average, the patient was middle aged and had a normal BMI. SIFFH was seen in patients as young as 16, and several studies reported on only young patients with SIFFH [10, 14, 20, 21].

MRI was the most commonly used imaging modality to diagnose SIFFH, and there has been extensive research on the diagnostic signs of SIFFH. Because of the similarity in presentation to osteonecrosis, it is important to distinguish between the two. SIFFH is characterized by a low signal intensity band on T1 weighted MRI and is commonly described as irregular and convex. Osteonecrosis has a smooth low intensity band due to circumscription of necrotic segments [22]. A BME pattern is another commonly described feature of SIFFH and osteonecrosis and is seen in most patients on MRI [11, 23]. BME is fluid exudation caused by the chronic inflammation and proliferating fibroblasts [15]. Based on our review, BME is a frequent concomitant sign of SIFFH on MRI. Sonoda et al. [23] described T2 imaging of SIFFH which had low intensity bands and BME and found that absence of BME could be related to progression to collapse. More research is needed to determine which diagnostic features affect prognosis of SIFFH.

In older studies, X-ray imaging was used to diagnose. These studies used the crescent sign, a less radiolucent linear defect, with a slight sclerotic rim which is typically associated with osteonecrosis [2, 8]. Histopathological confirmation was needed to differentiate between SIFFH and osteonecrosis [2]. Additionally, X-ray can be used when prior implants make visualization on MRI difficult [24]. Uchida et al. [15] used CT as an adjunct to MRI to visualize the fracture line. Overall, MRI findings have been clearly reported and is the most commonly used to identify SIFFH. The ongoing study did not find a difference in imaging modality leading to a difference in treatment.

Another important and rare disease of the hip to include in the differential is idiopathic transient osteoporosis of the hip. This pathology is seen typically in pregnant women in the last trimester, however, in recent studies, it is more prevalent in middle aged men [25, 26]. On imaging, there is a similar BME pattern and increased signal intensity on T2 MRI [27]. The etiology of the disease is unknown, however, microfractures are thought to be involved and the risk factors are similar to SIFFH. In contrast though, the disease is typically self-limiting and resolves in months [27].

Non-operative management was most commonly used for SIFFH. This includes rest, non-weight bearing with crutches and appropriate medical management. THA was the most commonly used surgical treatment in our review. The prevalence of THA use in SIFFH management is expected given the overall average age of patients in our review and the successful outcomes of the procedure. SIFFH was treated with THA presenting with diverse etiologies, such as organ transplant, systemic erythematous lupus, fatigue fracture, anorexia nervosa and Turner syndrome [10, 28–31].

Interestingly, in the majority of cases reviewed, SIFFH has been seen to resolve with non-operative measures such
### Table I. Overview of all studies included in systematic review

| Study                  | Level of evidence | Number of patients with SIFFH | Number of hips with SIFFH | Mean patient age (years ± SD) | Mean BMI (kg/m²) | Diagnosis imaging modality | Imaging finding | Treatment | Etiology                  | Follow-up (months) | Conversion to THA |
|------------------------|-------------------|-------------------------------|--------------------------|------------------------------|------------------|-----------------------------|----------------|----------|--------------------------|--------------------|-------------------|
| Hackney et al. [11]    | III               | M: 24                         | F: 27                    | 35*                          | 60 ± 16          | 27.4 ± 5.6                  | MRI            | BME: 44/51 | Non-op 19/35              | Chronic steroid use: 4 | 25 (2–105)        | 46% (16/35) |
| Kobayashi et al. [12]  | IV                | M: 5                          | F: 3                      | 11                           | 56±9             | MRI                         | BME: 10/11     | Non-op 10/11  | Radiation: 4              | Organ transplant: 3 | 58 (6–120)        | 9% (1/11)  |
| Iwasaki et al. [32]    | III               | M: 13                         | F: 20                     | 33                           | —                | MRI                         | —              | —        | Tumor induced osteomalacia: 11 | —                 | —                 | 21% (7/33) |
| Sonoda et al. [23]     | III               | M: 12                         | F: 25                     | 40                           | 55.8 (22–78)     | —                           | MRI            | BME: 40/40 | Non-op 26/40              | THA 4/40            | 21 (3–68)        | 10% (4/40) |
| Uchida et al. [15]     | IV                | M: 4                          | F: 5                      | 9                            | 49² (43–65)      | MRI or CT                   | BME: 9/9       | THA: 1/1  | Osteopenia + overexertion (load): 1 | —                 | 30 (12–56)        | 0% (0/9)   |
| Utsunomiya et al. [36] | V                 | M: 1                          |                           | 1                            | 59               | MRI                         | BME: 1/1       | THA: 1/1  | Acetabular over-coverage: 1 | —                 | —                 | —         |
| Kimura et al. [4]      | V                 | F: 1                          |                           | 1                            | 53               | MRI                         | BME: 1/1       | Non-op: 1 | Pregnancy and anorexia nervosa | —                 | —                 | 24 (0/1)   |
| Yamamoto et al. [34]   | IV                | M: 14                         | F: 25                     | 39                           | 44.1 ± 12.7      | MRI                         | BME: 39/39     | Non-op 24/39  | Chronic steroid use: 4 | —                 | —                 | —         |
| Ikemura et al. [37]    | III               | M: 1                          | F: 4                      | 5                            | 74 ± 12.8        | MRI                         | —              | Non-op 4/5  | Alcohol abuse: 1          | —                 | —                 | —         |
| Karahara et al. [29]   | V                 | F: 1                          |                           | 1                            | 40               | MRI                         | BME: 0/1       | THA 1/1   | Pregnancy and anorexia nervosa | 18 (1.2–18.2)     | 20% (2/10)        | 100% (1/1) |
| Ikemura et al. [19]    | III               | M: 5                          | F: 13                     | 18                           | 68 (41–85)       | MRI                         | —              | THA 18/18 | Chronic steroid use: 4 | —                 | 100% (18/18)      | —         |
| Baba et al. [38]       | V                 | F: 1                          |                           | 1                            | 65               | MRI                         | BME: 1/1       | Non-op 1/1 | Acetabular over-coverage: 1 | —                 | 20% (2/10)        | 0% (0/1)   |
| Miyamishi et al. [39]  | III               | M: 3                          | F: 7                      | 10                           | 70 (58–85)       | MRI                         | BME: 10/10     | Non-op 8/10 | Chronic steroid use: 1 | —                 | 7 (1.2–18.2)      | 20% (2/10) |
| Yamamoto et al. [20]   | IV                | M: 3                          | F: 2                      | 5                            | 22 (16–29)       | MRI                         | —              | Non-op 1/5  | —                        | Unclear            | 4 (2–9)           | 0% (0/5)   |
| Kim et al. [10]        | IV                | M: 27                         | F: 1                      | 34                           | 21.4 (19–26)     | MRI                         | BME: 34/34     | Non-op 21/34 | Fatigue fracture          | 57.4 (12–159)      | 12% (4/34)        | —         |

(continued)
| Study | Level of evidence | V | Number of patients with SIFFH | Number of hips with SIFFH | Mean patient age (years ± SD) | Mean BMI (kg/m²) | Diagnosis imaging modality | Imaging finding | Treatment | Etiology | Follow-up (months) | Conversion to THA |
|-------|-------------------|---|-------------------------------|--------------------------|-------------------------------|------------------|-----------------------------|----------------|-----------|----------|-------------------|------------------|
| Patel and Kamath [16] | V | M: 1 | 1 | 48 | — | MRI | BME: 1 | Core 1 | Undear | — | 0% (0/1) |
| Hamada et al. [40] | V | F: 1 | 2 | 69 | — | MRI | BME: 1 | THA 2/2 | Alkap tonuria | 20 | 100% (2/2) |
| Yoon et al. [41] | IV | M: 5 | 31 | 68.9 (53–90.3) | 22.8 (16–39.7) | MRI | — | Non-op 16/31 | THA 15/31 | — | 48% (15/31) |
| Ikemura et al. [37] | IV | M: 5 | 15 | 65.9 ± 14.1 | 24.1 ± 4.5 | MRI | BME: 15/15 | Non-op 8/15 | THA 7/15 | Chronic steroid use: 2 Alcohol abuse: 3 | 3.8 (3–5) | 47% (7/15) |
| Ghate and Samant [42] | V | M: 1 | 1 | 54 | — | MRI | — | Non-op 1/1 | — | 12 | 0% (0/1) |
| Kim et al. [43] | IV | M: 3 | 5 | 39 (33–46) | — | MRI | BME: 4/4 | Non-op 4/4 | — | — | 0% (0/4) |
| Sonoda et al. [24] | V | F: 1 | 1 | 70 | 21.6 | X-ray | — | THA 1/1 | Internal fixation | — | 100% (1/1) |
| Song et al. [14] | IV | M: 5 | 7 | 21 (20–22) | 21.9 (19.4–24.1) | MRI | BME: 7/7 | Non-op 4/7 | THA 1/7 | Drilling 1/7 Bone graft 1/7 | 40 (18–68) | 14% (1/7) |
| Ikemura et al. [44] | V | F: 2 | 2 | 26 | 43 | MRI | BME: 2/2 | Non-op 1/2 | TARO: 1/2 | Internal fixation: 2 | — | 0% (0/2) |
| Ohtsuka et al. [45] | V | M: 2 | 4 | 57 | 53 | MRI | BME: 2/2 | Non-op 2 | Renal transplant: 2 | — | 0% (0/2) |
| Sonoda et al. [13] | III | M: 7 | 7 | 30.1 ± 9 | 20.9 ± 1.7 | MRI | — | TARO: 7 | — | 3.6 ± 1.4 years | 0% (0/7) |
| Yamamoto et al. [46] | V | F: 1 | 1 | 65 | 24.1 | MRI | BME: 1 | THA: 1 | Osteoporosis | — | 100% (1/1) |
| Jo et al. [47] | III | M: 4 | 37 | 70.5 ± 7.4 | 24.3 ± 2.4 | MRI | — | Non-op: 8 | THA: 29 | — | 78% (29/37) |
| Yoon et al. [46] | V | M: 1 | 2 | 27 | 18.4 | MRI | BME: 1 | Non-op: 1 | Bone graft: 1 | THA: 1 | Fatigue | 24 | 0% (0/2) |
| Kawano et al. [49] | V | F: 1 | 1 | 74 | 28.4 | CT/X-ray | — | THA: 1 | — | — | 100% (1/1) |
| Miyamoto et al. [6] | IV | M: 5 | 5 | 72 (51–85) | — | MRI | BME: 27 | Non-op: 14 | THA: 13 | — | 28 (9–93) | 48% (13/27) |
| Buttaro et al. [5] | V | F: 4 | 4 | 70 (64–75) | 28.9 (24–31) | MRI | BME: 1/4 | Non-op: 1 | THA: 3 | — | 75% (3/4) |

Table I. (continued)
| Study                          | Level of evidence | Number of patients with SIFPH | Number of hips with SIFPH | Mean patient age (years ± SD) | Mean BMI (kg/m²) | Diagnosis imaging modality | Imaging finding | Treatment | Etiology | Follow-up (months) | Conversion to THA |
|--------------------------------|-------------------|-----------------|-----------------|------------------|-----------------|-----------------|-----------------|-----------|-----------|-------------------|-----------------|
| Ishihara et al. [50]          | III M: 1 F: 12    | 13              | 9               | 71.2 ± 7         | 23.9 ± 4.7      | MRI             | BME: 13/13     | Non-op: 13 | —         | —                 | 0% (0/13)       |
| Yamamoto et al. [2]           | IV F: 10          | 10              | 75.3 ± 7.1      | 25.7 ± 5.1       | MRI             | BME: 3/3        | THA: 10        | —         | —         | 100% (10/10)      |
| Lee et al. [33]               | IV M: 9           | 9               | 22.6 ± 4.4      | 22.5 ± 2.9       | MRI             | BME: 9/9        | Non-op: 6      | Drilling: 2 | Bone graft: 1 | 5.8 ± 2.1         | 0% (0/9)        |
| Fukui et al. [51]             | V F: 1            | 1               | 71              | 22.7             | MRI             | BME: 1          | THA: 1         | Dysplasia + inverted labrum | —                 | 100% (1/1)     |
| Yamamoto et al. [52]          | V M: 1 F: 1       | 2               | 29              | 26.8             | MRI             | BME: 2/2        | Non-op: 2      | —         | —         | 0% (0/2)          |
| Iwasaki et al. [21]           | IV M: 3 F: 2      | 5               | 23.4 (16–29)    | 23.1 (20.2–26.6) | MRI             | BME: 5/5        | Non-op: 1/5    | TARO: 4/5 | —         | 100% (0/5)        |
| Chouhan et al. [53]           | V M: 1            | 2               | 52              | 27.4             | MRI             | BME: 0/2        | Non-op: 2      | Tumor induced osteomalacia: 2 | —                 | 0% (0/2)       |
| Yamamoto et al. [54]          | V F: 1            | 1               | 55              | 27.4             | MRI             | BME: 1          | THA: 1         | Lupus     | —         | 100% (1/1)        |
| Yamamoto and Bullough [55]    | IV M: 2 F: 9      | 11              | 69 (61–78)      | MRI             | BME: 2/2        | THA: 11         | RDA            | —         | —         | 100% (11/11)      |
| Ikemura et al. [56]           | V F: 1            | 1               | 47              | 18.4             | MRI             | BME: 0/1        | Non-op: 1      | Renal transplant: 2 | —                 | 10% (0/1)      |
| Niimi et al. [57]             | V F: 1            | 1               | 75              | 27.4             | MRI             | BME: 1/1        | THA: 1         | —         | —         | 100% (1/1)        |
| Motoomura et al. [58]         | V F: 1            | 1               | 64              | 33.3             | MRI             | BME: 1/1        | THA: 1         | —         | —         | 100% (1/1)        |
| Iwasaki et al. [59]           | V F: 1            | 1               | 53              | 23.7             | MRI             | BME: 0/1        | Non-op: 1      | Liver transplant: 1 | —                 | 17% (0/1)      |
| Iwasaki et al. [62]           | IV M: 6 F: 19     | 25              | 56.9 (9–88)     | 20.8 (18.3–31.6) | MRI             | BME: 0/25       | Non-op: 2/5/25 | —         | —         | 24% (4-64)        |
| Huang et al. [28]             | V F: 1            | 1               | 51              | 18               | MRI             | BME: 1/1        | Hemiarthroplasty: 1 | —                 | 0% (0/1)       |
| Gerot et al. [30]             | IV M: 2 F: 5      | 7               | 50.3 (37–76)    | MRI             | BME: 0/25       | Non-op: 7/7     | Liver transplant: 2 | Chronic steroid use: 2 | 29% (11–39)     | 0% (0/7)       |
| Chan et al. [60]              | V F: 1            | 1               | 65              | MRI             | BME: 1/1        | Hemiarthroplasty: 1 | —                 | —         | —         | 0% (0/1)          |
| Zhao et al. [61]              | V F: 1            | 1               | 73              | 27.2             | MRI             | BME: 1/1        | THA: 1         | —         | —         | 100% (1/1)        |

(continued)
as non-weight bearing for 6–8 weeks [32]. This is an important distinction, as it is in contrast to the findings in osteonecrosis which presents similarly, yet most often progresses to degenerative joint disease [33]. Therefore, proper diagnosis is the first hurdle for the clinician. Several studies reported on patients, typically younger ones, which were previously misdiagnosed as osteonecrosis and received drilling, rod insertion and THA [10, 14, 33]. It is less clear in the literature as to what causes worsening pain or collapse of the femoral head on imaging in some patients. Because of the diversity of etiologies of SIFFH, it is difficult to highlight reasons for worsening and even among similar etiological cohorts there exists variation of recovery or worsening.

Surgical options for patients under 50 years old with SIFFH were more diverse, as attempts at hip preservation may be considered due to longer patient life expectancy and high activity level. TARO was the most common surgical procedure amongst the hip preservation patients and second most common overall after THA. Due to the common anterosuperior location of SIFFH, TARO has been shown to be effective management [13, 20, 21, 23, 32, 34, 35]. Yamamoto et al. [20] reported on four patients that underwent TARO and found no evidence of further collapse and excellent Harris Hip scores (HHS) at 2 years of follow-up. Sonoda et al. had similarly positive results in seven patients with a mean follow-up of 3.6 years and found the technique to be successful with excellent HHS. While longer follow-up and more patients are needed to definitively show the success of the technique, initial results are promising; this specialized technique may be training and institution dependent. Hip arthroscopy was the third most commonly reported procedure. Uchida et al. [15] reported on a cohort of nine patients that underwent hip arthroscopy for pre-collapse SIFFH and had excellent modified HHS at short-term follow-up. Acetabular labral tears were found in all patients, and a mix of femoroacetabular impingement and dysplasia morphology was found. Arthroscopic fragment fixation with hydroxyapatite poly-lactate acid (HA/PLLA) composite pins were used in the SIFFH lesion in addition to surgical management of the bony and soft tissue hip disease. Similarly, the results are promising but longer follow-up and more patients are needed. Another technique with positive post-operative results was core hip decompression with bone void filler as reported by Patel and Kamath [16]. While it is only one case, it represents another potential option that is less invasive than TARO. Mean modified Harris Hip score was considerably higher than the PASS level of 74 as reported by Chahal et al. [18].

### Table 1. (continued)

| Study          | Level of evidence | Number of patients with SIFFH with imaging finding | Number of hips with SIFFH | Mean BMI (kg/m²) | Mean patient age (years ± SD) | Imaging modality | Treatment | Diagnosis imaging finding | Imaging finding | Follow-up (months) | Conversion to THA | THA conversion rate (% ± SD) | Non-op, non-operative management |
|---------------|-------------------|--------------------------------------------------|---------------------------|------------------|-----------------------------|-----------------|-----------|--------------------------|----------------|-------------------|----------------|------------------------|-----------------------------|
| Yamamoto et al. [62] | V | F: 1 | 1 | MRI | 59 | BME: 1/1 | THA: 1 | — | Hemiarthroplasty: 1 | — | 100% (1/1) | 0% (0/1) | |
| Watanabe et al. [7] | V | F: 1 | 1 | MRI | 80 | BME: 1/1 | THA: 1 | — | THA: 1 | — | 100% (1/1) | 100% (1/1) | |
| Lee et al. [63] | V | F: 1 | 1 | MRI | 22.3 | BME: 1/1 | THA: 1 | — | Lupus | — | 100% (1/1) | 100% (1/1) | |
| Bhiman et al. [9] | V | F: 1 | 1 | MRI | 62 | BME: 1/1 | THA: 1 | — | THA: 1 | — | 100% (1/1) | 100% (1/1) | |
preservation technique results are promising in small groups of patients reported, and more research is needed as to whether they can prevent further collapse of the femoral head over the long term and in larger patient numbers. Our study was not without limitations. Because SIFFH is relatively uncommon, most articles found were case reports with low numbers of patients. While compiling them helps to draw conclusions, there exists a need for more robust studies with less potential bias. Additionally, we did not find consistent long-term post-operative follow-up in most studies; therefore, the differences in etiology and treatment we presented have an unknown impact on these patient post-operative outcomes. This makes it difficult to draw conclusions about the proper treatments. Longer follow-up would allow for better conclusions on treatment efficacy in preventing femoral head collapse and the durability of both non-surgical and surgical treatment options. Also, the etiology and diagnostic standards for SIFFH has evolved over the past decades; therefore, it is always possible that patients captured in earlier studies might have different outcomes impacting overall results.

CONCLUSION

A review of the literature identified that SIFFH should be considered as a cause of acute hip pain in elderly and younger patients that are subject to high stress or relative osteopenic conditions. A majority had symptom resolution with non-operative management. A minority had symptom improvement with non-operative management and those who worsened were typically managed surgically. SIFFH has evolved over the past decades; therefore, it is difficult to draw conclusions about the proper treatments. Long-term follow-up would allow for better conclusions on treatment efficacy in preventing femoral head collapse and the durability of both non-surgical and surgical treatment options. Additionally, we did not find consistent long-term post-operative follow-up in most studies; therefore, the differences in etiology and treatment we presented have an unknown impact on these patient post-operative outcomes. This makes it difficult to draw conclusions about the proper treatments. Longer follow-up would allow for better conclusions on treatment efficacy in preventing femoral head collapse and the durability of both non-surgical and surgical treatment options. Also, the etiology and diagnostic standards for SIFFH has evolved over the past decades; therefore, it is always possible that patients captured in earlier studies might have different outcomes impacting overall results.

Table II. Studies involving subchondral insufficiency fractures of the femoral head (SIFFH) managed with hip preservation surgery

| Study          | Number of patients | Number of hips treated with preservation | Mean patient age (years ± SD) | Mean BMI (kg/m²) | Treatment | Follow-up (months) | Outcome measure | Last follow-up score | Complications/ revisions |
|----------------|--------------------|------------------------------------------|-------------------------------|------------------|------------|-------------------|-----------------|---------------------|-------------------------|
| Uchida et al. [15] | M: 4 F: 5         | 9                                        | 49.0 (43–65)                 | 24.3 (20–31)     | Hip arthroscopy | 30 (12–56)       | mHHS            | 96.8 (82.5–100)      | None                    |
| Sonoda et al. [13] | M: 7 F: 2        | 7                                        | 30.1 ± 9                     | 20.9 ± 1.7       | TARO       | 43.2 ± 16.8       | HHS             | 96.9 ± 3.8          | None                    |
| Yamamoto et al. [20] | M: 2 F: 2       | 4                                        | 22 (16–29)                   | 23.1             | TARO       | 49 (109–24)       | HHS             | 98.6 ± 2.3          | None                    |
| Lee et al. [33]    | M: 3 F: 2         | 3                                        | 20.7 ± 0.6                   | 19.9 ± 3.0       | Drilling: 2 | 94.4 ± 16.8       | HHS             | 89 ± 11.3           | None                    |
| Patel and Kamath [16] | M: 1 F: 0       | 1                                        | 48                            | —                | Core + bone filler | 18              | Clinical Full return to ADLs and sports | None |
2. Yamamoto T, Bullough PG. Subchondral insufficiency fracture of the femoral head: a differential diagnosis in acute onset of coxa-arthrosis in the elderly. *Arthritis Rheum* 1999; 42: 2719–23.

3. Yamamoto T. Subchondral insufficiency fractures of the femoral head. *Clin Orthop Surg* 2012; 4: 173–80.

4. Kimura T, Goto T, Hamada D et al. Subchondral insufficiency fracture of the femoral head caused by excessive lateralization of the acetabular rim. *Case Rep Orthop* 2016; 2016: 4371679.

5. Buttaro M, Gonzalez Della Valle A, Morandi A et al. Insufficiency subchondral fracture of the femoral head report of 4 cases and review of the literature. *J Arthroplasty* 2010; 18: 271–5.

6. Watanabe W, Itoi E, Yamada S. Early MRI findings of rapidly destructive coxarthrosis. *Skeletal Radiol* 2002; 31: 35–8.

7. Yamamoto T, Schneider R, Bullough PG. Insufficiency subchondral fracture of the femoral head. *Am J Surg Pathol* 2000; 24: 464–8.

8. Bhimani R, Singh P, Bhimani F. Rapidly progressive hip disease—a rare entity in Korean population. *Int J Surg Case Rep* 2018; 53: 486–9.

9. Kim S, Oh S, Cho C et al. Fate of subchondral fatigue fractures of femoral head in young adults differs from general outcome of fracture healing. *Injury* 2016; 47: 2789–94.

10. Hackney LA, Lee MH, Joseph GB et al. Subchondral insufficiency fractures of the femoral head: associated imaging findings and predictors of clinical progression. *Eur Radiol* 2016; 26: 1929–41.

11. Kobayashi H, Ito N, Akiyama T et al. Prevalence and clinical outcomes of hip fractures and subchondral insufficiency fractures of the femoral head in patients with tumour-induced osteomalacia. *Int Orthop* 2017; 41: 2597–603.

12. Sonoda K, Motomura G, Ikemura S et al. Favorable clinical and radiographic results of transtrochanteric anterior rotational osteotomy for collapsed subchondral insufficiency fracture of the femoral head in young adults. *JB JS Open Access* 2017; 2: e0013.

13. Song W, Yoo J, Koo K et al. Subchondral fatigue fracture of the femoral head in military recruits. *J Bone Joint Surg Am* 2004; 86: 1917–24.

14. Uchida S, Noguchi M, Utsunomiya H et al. Hip arthroscopy enables classification and treatment of precollapse subchondral insufficiency fracture of the femoral head associated intra-articular pathology. *Knee Surg Sports Traumatol Arthrosc* 2018; 26: 2527–35.

15. Patel H, Kamath A. Subchondral insufficiency fracture of the femoral head. *Arch Bone Jt Surg* 2016; 4: 264–8.

16. Liberati A, Altman D, Tetzlaff J et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *Br Med J* 2009; 339: b2700.

17. Chahal J, Van Thiel GS, Mather RC 3rd et al. The patient acceptable symptomatic state for the modified Harris Hip score and hip outcome score among patients undergoing surgical treatment for femoroacetabular impingement. *Am J Sports Med* 2015; 43: 1844–9.

18. Ikemura S, Mawatari T, Matsui G et al. The depth of the low-intensity band on the T1-weighted MR image is useful for distinguishing subchondral insufficiency fracture from osteonecrosis of the collapsed femoral head. *Arch Orthop Trauma Surg* 2018; 138: 1053–8.

19. Yamamoto T, Iwasaki K, Iwamoto Y. Transtrochanteric rotational osteotomy for a subchondral insufficiency fracture of the femoral head in young adults. *Clin Orthop Relat Res* 2010; 468: 3181–5.

20. Iwasaki K, Yamamoto T, Motomura G et al. Subchondral insufficiency fracture of the femoral head in young adults. *J Clin Imaging* 2011; 35: 208–13.

21. Iwasaki K, Yamamoto T, Motomura G et al. Prognostic factors associated with a subchondral insufficiency fracture of the femoral head. *Br J Radiol* 2012; 85: 214–8.

22. Sonoda K, Yamamoto T, Motomura G et al. Fat-suppressed T2-weighted MRI appearance of subchondral insufficiency fracture of the femoral head. *Skeletal Radiol* 2016; 45: 1515–21.

23. Sonoda K, Yamamoto T, Motomura G et al. Subchondral insufficiency fracture of the femoral head after internal fixation for femoral neck fracture: histopathological investigation. *Skeletal Radiol* 2014; 43: 1151–3.

24. Kim YL, Nam KW, Yoo JJ et al. CT evidence for subchondral trabecular injury of the femoral head in transient osteoporosis of the hip: a case report. *J Korean Med Sci* 2010; 25: 192–5.

25. Rishi V, Wahi P, Mahajan A. Transient osteoporosis of hip (migratory). *JK Sci* 2008; 10: 194–6.

26. Mirza R, Ishaq S, Amjad H. Transient osteoporosis of the hip. *J Pak Med Assoc* 2012; 62: 196–8.

27. Huang K, Hsu W, Lee K et al. Subchondral insufficiency fracture with rapid collapse of the femoral head in a patient with Turner’s syndrome. *Rheumatology* 2005; 44: 826–7.

28. Kasahara K, Mimura T, Moritani S et al. Subchondral insufficiency fracture of the femoral head in a pregnant woman with pre-existing anorexia nervosa. *Tohoku J Exp Med* 2018; 245: 1–5.

29. Gerot I, Demondion X, Bera A et al. Subchondral fractures of the femoral head: a review of seven cases. *Jt Bone Spine* 2004; 71: 131–5.

30. Yamamoto T, Schneider R, Iwamoto Y et al. Subchondral insufficiency fracture of the femoral head in a patient with systemic lupus erythematosus. *Ann Theum Dis* 2006; 65: 837–8.

31. Iwasaki K, Yamamoto T, Motomura G et al. Common site of subchondral insufficiency fractures of the femoral head based on three-dimensional magnetic resonance imaging. *Skeletal Radiol* 2016; 45: 105–13.

32. Lee Y-K, Yoo JJ, Koo K-H et al. Collapsed subchondral fatigue fracture of the femoral head. *Orthop Clin N Am* 2009; 40: 259–65.

33. Yamamoto T, Karasuyama K, Iwasaki K et al. Subchondral insufficiency fracture of the femoral head in males. *Arch Orthop Trauma Surg* 2014; 134: 1199–203.

34. Ikemura S, Yamamoto T, Motomura G et al. The utility of clinical features for distinguishing subchondral insufficiency fracture from osteonecrosis of the femoral head. *Arch Orthop Trauma Surg* 2013; 133: 1623–7.

35. Utsunomiya T, Yamamoto T, Motomura G et al. The clinicopathologic findings of a subchondral insufficiency fracture of the femoral head in a male patient: a case report. *Skeletal Radiol* 2016; 1425–9.
37. Ikemura S, Yamashita A, Harada T et al. Clinical and imaging features of a subchondral insufficiency fracture of the femoral head after internal fixation of a femoral neck fracture: a comparison with those of post-traumatic osteonecrosis of the femoral head. Br J Radiol 2016; 89: 20150725.

38. Baba S, Motomura G, Ikemura S et al. Femoral head fracture similar to slipped capital femoral epiphysis in an elderly woman with antecedent hip osteoarthritis after subchondral insufficiency fracture: A case report. J Orthop Sci 2017; 4–7.

39. Miyanishi K, Hara T, Kaminomachi S et al. Contrast-enhanced MR imaging of subchondral insufficiency fracture of the femoral head: a preliminary comparison with that of osteonecrosis of the femoral head. Arch Orthop Trauma Surg 2009; 129: 583–9.

40. Hamada T, Yamamoto T, Shida J et al. Subchondral insufficiency fracture of the femoral head in a patient with alkaptonuria. Skeletal Radiol 2014; 43: 827–30.

41. Yoon PW, Kwak HS, Yoo JJ et al. Subchondral Insufficiency Fracture of the Femoral Head in Elderly People. J Korean Med Sci 2014; 29: 593.

42. Ghate SD, Samant A. Subchondral Insufficiency Fracture of Femoral head: Uncommon cause of Hip pain in Elderly. J Orthop Case Reports 2012; 2: 7–9.

43. Kim JW, Jeong, Yoo J et al. Subchondral Fracture of the Femoral Head in Healthy Adults. 2007, DOI: 10.1097/BLO.0b013e3181577212.

44. Ikemura S, Hara T, Nakamura T. Subchondral insufficiency fracture of the femoral head: a report of two cases with a history of internal fixation of a femoral neck fracture. 2013: 849–51.

45. Ohtsuru T, Yamamoto T, Murata Y et al. Subchondral insufficiency fracture of the femoral head: A report of two cases with a history of internal fixation of a femoral neck fracture. 2013; 129: 410–3.

46. Yamamoto T, Schneider R, Bullough PG. Insufficiency subchondral fracture of the femoral head. Am J Surg Pathol 2000; 24: 464–8.

47. Jo W, Lee W, Chae D et al. Decreased lumbar lordosis and deficient acetabular coverage are risk factors for subchondral insufficiency fracture. J Korean Med Sci 2016; 31: 1650–5.

48. Yoon PW, Yoo JJ, Yoon KS et al. Case report: multifocal subchondral stress fractures of the femoral heads and tibial condyles in a young military recruit. Clin Orthop Relat Res 2012; 470: 944–9.

49. Kawano K, Motomura G, Ikemura S et al. Subchondral insufficiency fracture of the femoral head in an elderly woman with symptomatic osteoarthritis of the contralateral hip. J Orthop Sci 2018; 43–5.

50. Ishihara K, Miyanishi K, Ihara H et al. Subchondral insufficiency fracture of the femoral head may be associated with hip dysplasia: a pilot study. Clin Orthop Relat Res 2010; 468: 1331–5.

51. Fukui K, Kaneuji A, Fukushima M et al. Imaging and histopathological evaluation of a cystlike formation in subchondral insufficiency fracture of the femoral head: A case report and literature review. Int J Surg Case Rep 2014; 5: 324–9.

52. Yamamoto T, Nakashima Y, Shuto T et al. Subchondral insufficiency fracture of the femoral head in younger adults. 2007; 8: 38–42.

53. Chouhan V, Agrawal K, Vinothkumar TK et al. Bilateral insufficiency fracture of the femoral head and neck in a case of oncogenic osteomalacia. J Bone Joint Surg Br 2010; 92: 1028–31.

54. Yamamoto T, Schneider R, Iwamoto Y et al. Subchondral insufficiency fracture of the femoral head in a patient with systemic lupus erythematosus. Ann Rheum Dis 2006; 65: 837–8.

55. Yamamoto T, Bullough PG. The role of subchondral insufficiency fracture in rapid destruction of the hip joint: A preliminary report. Arthritis Rheum 2000; 43: 2423–7.

56. Ikemura S, Yamamoto T, Nakashima Y et al. Bilateral subchondral insufficiency fracture of the femoral head after renal transplantation: a case report. Arthritis Rheum 2005; 52: 1293–6.

57. Niimi R, Hasegawa ÂEM, Sudo ÆA. Rapidly destructive coxopathy after subchondral insufficiency fracture of the femoral head. 2005: 410–3.

58. Motomura G, Yamamoto T, Miyanishi K et al. Subchondral insufficiency fracture of the femoral head and acetabulum: a case report. J Bone Joint Surg Am 2002; 84-A: 1205–9.

59. Iwasaki K, Yamamoto T, Nakashima Y et al. Subchondral insufficiency fracture of the femoral head after liver transplantation. Skeletal Radiol 2009; 38: 925–8.

60. Chan CC, Li A, Fan WC et al. Subchondral insufficiency fracture of the femoral head. Hong Kong Med J 2006; 12: 460–2.

61. Zhao G, Yamamoto T, Ikemura S et al. A histopathological evaluation of a concave-shaped low-intensity band on T1-weighted MR images in a subchondral insufficiency fracture of the femoral head. Skeletal Radiol 2010; 39: 185–8.

62. Yamamoto T, Takabatake K, Iwamoto Y. Subchondral Insufficiency Fracture of the Femoral Head Resulting in Rapid Destruction of the Hip Joint. Am J Roentgenol 2002; 178: 435–7.

63. Lee Y, Motomura G, Yamamoto T et al. Rapidly destructive arthrosis of the hip joint in a young adult with systemic lupus erythematosus. Rheumatol Int 2015; 35: 1753–7.