*Original Article*

# The Radiographic Prevalence of Cam Morphology in Thai Patients Undergoing Total Hip Replacement: A 15-Year Review

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***Background:*** Total hip replacement (THR) is a common procedure that can relieve the pain and improve the functions of patients with advanced osteoarthritis (OA) of the hip. Femoroacetabular impingement (FAI), with either a cam or pincer morphology, produces chondral or labral damage that can develop into hip OA. This condition, which is commonly unrecognized, can be identified in some patients undergoing a THR.

***Objective:*** The present study aimed to determine the radiographic prevalence of cam morphology and the causes of THR during a 15-year period.

***Materials and Methods:*** The authors retrospectively reviewed the medical records of all THR cases at a tertiary hospital in Thailand between 2002 and 2017 to identify the causes of the THRs. For patients with primary hip OA, pre-operative radiographs were reviewed by two orthopedic surgeons to detect cam and pincer morphologies. The patients were subsequently classified into three groups: "abnormal morphology", "no abnormal morphology", and "indeterminate morphology". The descriptive statistics for this study were summarized.

***Results:*** Of the 1,250 patients (providing 1,475 hips that underwent THR) in the study, 856 (68%) were female. The mean age of the study cohort was 54.4±15.1 years. Idiopathic avascular necrosis (AVN) was the most common etiology (390 cases; 27%). The most common disease among the very young age patients (≤30 years) was AVN due to drugs (40 cases; 35%). Of the 167 patients with primary hip OA, 37 hips (22%) had abnormal morphology (34 hips with cam morphology, 4 hips with pincer morphology, and one patient with both morphologies).

***Conclusion:*** Idiopathic AVN was the most common cause of the THRs. Cam morphology was found in at least one-fifth of the cases with advanced primary hip OA.

***Keywords:*** Cam morphology, Femoroacetabular impingement, Total hip replacement, Radiographic prevalence, Osteoarthritis

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Total hip replacement (THR) is a procedure that can relieve the pain and improve the functions of patients with severe hip osteoarthritis (OA). Many causes of hip OA may lead to a THR, for example, avascular necrosis (AVN) of the femoral head, primary OA, hip dysplasia, and a recently recognized condition of femoroacetabular impingement (FAI)[1-3]. FAI syndrome is defined as a triad of symptoms, clinical signs, and image findings[4]. The primary symptom is pain at the hip or groin which is related to motion or position. The clinical signs include a positive impingement test or limited hip motion. The presence of a cam or pincer morphology, determined by radiographic measurement, is required for a diagnosis of FAI syndrome[4]. Cam morphology refers to an abnormal, bony morphology of the femoral head-neck junction, whereas pincer morphology is characterized by either global or focal over coverage of the acetabular rim[5]. Regarding FAI, repetitive abnormal contact during hip motions results in chondrolabral damage and the development of hip OA[6,7]. Cam morphology may lead to anterosuperior acetabular cartilage damage with a separation between the labrum and cartilage, which has been proven not only to increase the risk of OA but also to develop OA more rapidly than otherwise[1,7,8]. By comparison, pincer morphology creates a rather slow process of degeneration and less severe damage to the acetabular rim[6]. Nevertheless, a recent cohort study revealed a protective effect of pincer morphology against the development of OA[9]. The early detection and treatment of patients with FAI syndrome, especially those with cam-type FAI, improves patients' symptoms and may decrease the risk of developing hip

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OA[10]. However, there have only been a limited number of studies of Thai patients undergoing a THR that identified, firstly, the incidences of cam and pincer morphologies in primary hip OA and, secondly, the prevalence of the leading causes of hip OA. The current study aimed to establish the radiographic rate of cam morphology in Thai patients who had a THR, and the frequency of the causes of THRs over a 15-year period.

## Materials and Methods

This retrospective study was approved by the Institutional Review Board. The medical records and preoperative radiographs of patients who received a THR at Siriraj Hospital, a tertiary care hospital, between 2002 and 2017 were reviewed. The inclusion criteria were patients who were older than 15 years, had undergone a THR, had complete medical records in the hospital's database, and had pre-operative radiographs of the affected hip. Excluded were patients who were foreign or had undergone a THR owing to a recent hip fracture.

The following patient data were collected from the medical records: age, sex, and side of involvement. The diagnosis and/or reason for the patients undergoing a THR were confirmed by the inpatient medical records, operative notes, and the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10 version, 2014).

All patients diagnosed as having primary hip OA were assessed for radiographic measurement. The pre-operative radiographs comprised anteroposterior (AP) pelvic views and lateral hip views (cross-table or frog-leg view). The set of radiographs closest to the time of surgery were reviewed in order to evaluate the cam morphology at the femoral head-neck junction and the pincer morphology of the acetabular rim[11-13]. Cam morphology is characterized by an aspherical femoral head with a flat or convex head-neck junction. This type of morphology is defined as having a pistol grip deformity, a herniation pit, or a triangular index of more than 2-mm on an AP pelvic radiograph[14,15]. In addition, an alpha angle exceeding 55 degrees on either the AP pelvic or the lateral radiograph is considered as cam morphology[4,16]. In comparison, pincer morphology has either a localized or a generalized acetabular over coverage, defined by a positive finding of at least one of the following: a lateral central-edge angle of more than 40 degrees, a Tonnis angle of less than 0 degree, and the presence of the cross-over sign[11,16]. All radiographs were reviewed by two orthopedic surgeons who specialized in sports medicine to determine the inter-rater reliability. Each hip was classified into one of three groups: "abnormal morphology", "no abnormal morphology", and "indeterminate morphology" (Figure 1). The first group comprised hips with definite cam or pincer morphology. In contrast, the last group consisted of hips that had a degenerative process that made it difficult to exclude the radiographic characteristics of FAI (Figure 1). Inter-rater variability was resolved by consensus with the senior author (PL).

### *Statistical analysis*

Descriptive statistics were used to summarize the demographic data. All categorical data were reported as a number or percentage, while the continuous data were reported either as the mean and standard deviation if normally distributed, or as the median with a range for the non-normally distributed data. For comparisons of the demographic data of FAIs, Fisher's exact test or the independent t-test was used, as appropriate. The inter-rater reliability of the radiographic interpretation was measured using Cohen's kappa coefficient. A value <0 indicated no agreement, while 0 to 0.20 represented slight, 0.21 to 0.40 moderate, 0.61 to 0.80 substantial, and 0.80 to 1.00 almost perfect agreement[17]. A *p*-value of 0.05 was considered to be the threshold for significance. All statistical analyses were calculated using SPSS Statistics for Windows, version 18.0 (SPSS Inc, Chicago, Illinois, USA) and STATA/SE, version 14 (StataCorp LP, College Station, Texas, USA).

## Results

Of the 1,250 patients included in the study, 856 (68%) were female. The mean age of the study cohort was 54.4±15.1 years. A total of 1,475 hips underwent THR, with 632 (43%) right THRs, 618 (42%) left THRs, and 225 (15%) both-sided THRs. The etiologies leading to the THRs are listed in Table 1. The most common was idiopathic AVN of the femoral head, accounting for 390/1,475 hips (26.6%); it was followed by AVN due to drugs (13.8%) and secondary OA from trauma (12.5%). Primary hip OA was the fourth most common etiology, with 167 hips (11.4%). Only 2 hips (0.1%) were diagnosed as having FAI during the 15-year study period. All data were also classified into three age groups: aged <30 years (very young), 31 to 50 years (young), and >50 years (old)[18,19]. The etiologies by age group are also listed in Table 1.

Regarding AVN (or osteonecrosis) of the femoral head, cases were categorized as idiopathic AVN, AVN due to drugs, AVN due to previous trauma, and other secondary AVN, in accordance with ICD-10 Version 2014. Nearly half of this case series (725 cases, 49.4%) were AVN: idiopathic AVN accounted for 26.6%, AVN due to drugs represented 13.8%, AVN due to previous trauma was 5.6%, while other secondary AVN comprised 3.4% of the cases. AVN due to drugs was the most common etiology for the THRs in the very young patient age-group (40 hips, 35.1%). Idiopathic AVN was the most common disease in both the young patient age-group (119 hips, 27.2%) and the old patient age-group (263 hips, 28.7%).

As to the 167 hips (157 patients) with primary hip OA, 117 patients (75%) were female, with a mean age of 67±10 years. There were 82 (52%) right THRs, 65 (41%) left THRs, and 10 (7%) THRs of both sides. All cases had pre-operative AP radiographs, and 117 (70%) had lateral hip radiographs. Thirty-seven hips (22%) had abnormal morphology (cam or pincer), while 57 hips (34%) had no abnormal morphology (Figure 2). The remaining 73 hips (44%) were indeterminate in that they could not be excluded

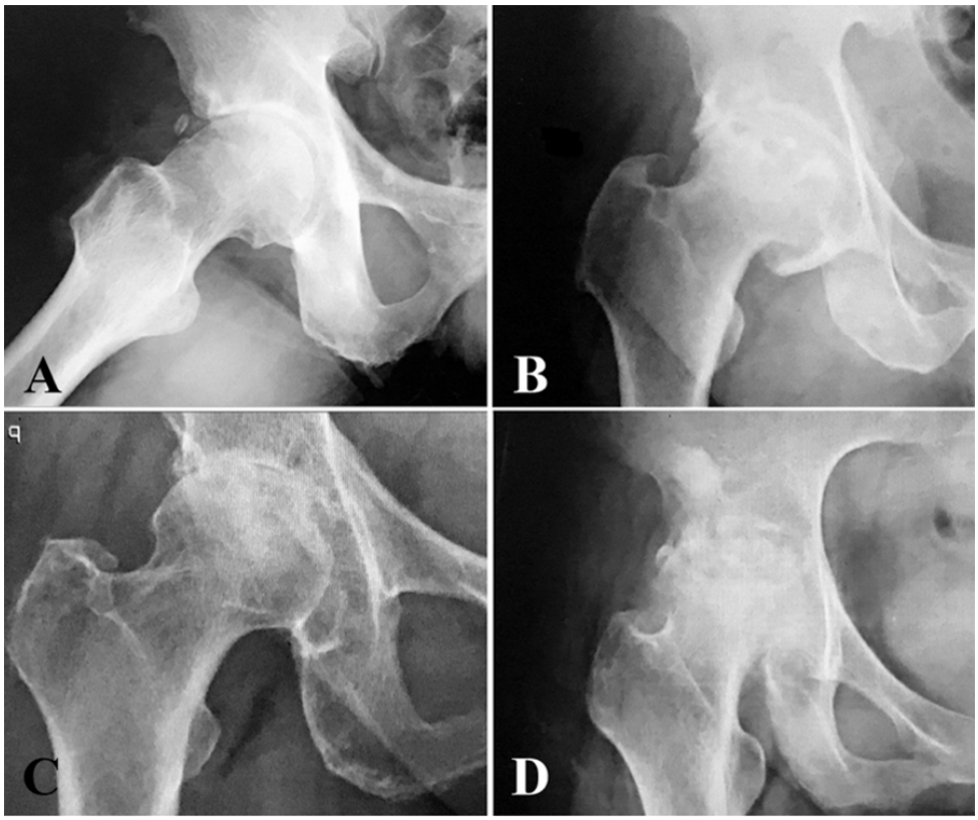


**Figure 1.** Examples of preoperative hip radiographs that were evaluated for cam morphology of the proximal femur and pincer morphology of the acetabulum: A) The lateral radiograph of the right hip showed an alpha angle >55 degrees, which was classified as "definite cam morphology", B) The anteroposterior radiograph showed a lateral central-edge angle of more than 40 degrees, which was classified as "definite pincer morphology", C) An osteoarthritis of the right hip without radiographic characteristics of cam or pincer morphology, which was classified as "no-cam morphology" and "no-pincer morphology", D) A severe degree osteoarthritis of the right hip that was impossible to distinguish between cam or pincer morphology, and which was classified as "indeterminate morphology".

**Table 1.** Common etiologies for total hip replacement classified by age group

| Diagnosis | Age group, n (%) | | | Total n (%) (n = 1,475) |
|---|---|---|---|---|
| | ≤30 years (n = 114) | 31 to 50 years (n = 438) | >50 years (n = 923) | |
| Idiopathic AVN | 8 (7) | 119 (27.2)* | 263 (28.7)* | 390 (26.6)* |
| AVN due to drugs | 40 (35.1)* | 87 (19.9) | 76 (8.3) | 203 (13.8) |
| Secondary OA from trauma | 11 (9.6) | 53 (12.1) | 120 (13.1) | 184 (12.5) |
| Primary OA | 0 (0) | 15 (3.4) | 152 (16.6) | 167 (11.4) |
| Hip dysplasia | 5 (4.4) | 33 (7.5) | 105 (11.5) | 143 (9.7) |
| Secondary OA from inflammatory disease | 25 (21.9) | 42 (9.6) | 37 (4) | 104 (7.1) |
| AVN due to previous trauma | 5 (4.4) | 28 (6.4) | 49 (5.3) | 82 (5.6) |
| Others | 20 (17.6) | 61 (13.9) | 121 (12.5) | 202 (13.3) |

AVN = avascular necrosis, OA = osteoarthritis
* This represents the most common etiology for each age group

for either cam or pincer morphologies due to advanced OA. Of the 37 hips with abnormal morphologies, cam morphology was found in 34 hips (20%). There were 4 hips (2%) with pincer morphology and one hip (0.6%) with a combination of cam and pincer morphologies (Table 2). The average age of the patients with abnormal morphology was 65.6±8.8 years. The demographic data of the patients with cam or pincer morphologies are listed in Table 3. There were more males (16, 37.1%) in the cam morphology group than in the no-cam morphology group ($p$<0.01). The mean ages, gender, and side of involvement of the patients in the cam and pincer morphology groups were not statistically different ($p$>0.05). A substantial inter-rater reliability was found, with a kappa of 0.84 (95% CI, 0.73 to 0.96, with an agreement of 89.6%) for the cam morphology. As to the pincer morphology, there was also substantial agreement, with a kappa of 0.91 (95% CI, 0.76 to 1, with an agreement of 95.7%).

**Discussion**

There are many etiologies of hip OA and they vary around the world. In this study of Thai patients, nearly half had a THR due to AVN of the femoral head. Idiopathic AVN was the most common cause of THR, and it was most commonly found in the young (31 to 50 years) and old (>50 years) patients. AVN due to drugs was the leading cause of THR in the very young age group (<30 years). Interestingly, hip dysplasia was not the leading cause of THR in this series (9.7%), despite it's being reported to be a leading cause in many countries[6,20,21]. For instance, developmental dysplasia of the hip was associated with 62% of cases of hip OA (155 out of 250 hips) in the Japanese population[20]. Similarly, a retrospective study of Caucasian and African cases showed a high incidence of hip dysplasia leading to the development of hip OA[6,21]. Thus, AVN is the essential etiology of THR in Thai patients.

The prevalence of cam or pincer morphology varies among different populations. In a study by Takeyama et al of the radiographic prevalence of FAI in Japanese patients who had a THR, it was found that only 6 out of 946 cases (0.6%) had FAI[3]. By comparison, Hashimoto et al found that cam impingement deformity was present in 22% of 88 Japanese patients who had hip OA with unknown etiology[20]. From a large population-based survey of 4,151 individuals in Denmark, Gosvig et al found incidences of 19.6% and 5.2% for pistol grip deformity (cam morphology), and 15.2% and 19.4% for deep acetabular socket (coxa profunda and protrusio acetabuli) in males and females, respectively[10]. Studying the prevalence of radiographic FAI in younger patients (<55 years) who received a THR in Canada, Lung et al found prevalences of 36% for definite FAI, 33% for no FAI, and 31% for subjects for whom FAI could not be excluded due to advanced OA. Of the 27 subjects in their series who had definite radiographic FAI, 5 cam-FAI, 13 pincer-FAI, and 9 mixed-type FAI were identified[22].

There has been an increasing interest in the FAI syndrome since 2003 when Ganz et al demonstrated that this condition causes repetitive trauma to the hip and develops into OA[5]. In addition, both open surgical dislocation and arthroscopic surgery have been developed as treatment for this condition. Therefore, the number of patients who have been diagnosed with FAI syndrome has been rising rapidly. In the past, radiographic cam and pincer morphologies were unrecognized, and this group of patients was diagnosed with primary hip OA. In the current research, there were only 2 cases (0.1%) over the 15-year study period who were diagnosed as having FAI at the time of their THR surgery.

**Table 2.** Radiographic prevalence of cam and pincer morphologies in the patients with primary hip OA

| Bony morphology | Number (%) (n = 167 hips) |
|---|---|
| Cam morphology | |
| Definite cam | 34 (20) |
| No cam | 60 (36) |
| Indeterminate | 73 (44) |
| Pincer morphology | |
| Definite pincer | 4 (2) |
| No pincer | 89 (53) |
| Indeterminate | 74 (45) |

**Table 3.** Demographic data of cam and pincer morphologies in primary hip OA

| Demographic data | Cam morphology | | $p$-value | Pincer morphology | | $p$-value |
|---|---|---|---|---|---|---|
| | Definite cam (n = 34) | No cam (n = 60) | | Definite pincer (n = 4) | No pincer (n = 89) | |
| Age, mean ± SD | 65.8±8.5 | 68.1±8.6 | 0.24 | 64.3±12.1 | 67.6±8.3 | 0.65 |
| (range), years | 67.5 (48 to 81) | 69 (48 to 84) | | 65.5 (49 to 77) | 68 (48 to 84) | |
| Gender, n (%) | | | | | | |
| Male | 16 (47.1) | 8 (13.3) | <0.01 | 2 (50) | 21 (23.6) | 0.26 |
| Female | 18 (52.9) | 52 (86.7) | | 2 (50) | 76 (76.4) | |
| Side, n (%) | | | | | | |
| Left | 14 (41.2) | 22 (36.7) | 0.67 | 2 (50) | 34 (38.2) | 0.64 |
| Right | 20 (58.8) | 38 (63.3) | | 2 (50) | 55 (61.8) | |

However, cam or pincer morphologies could be identified in 27% of the pre-operative radiographs of the patients with primary hip OA. The prevalence of cam morphology in the present study was comparable to the prevalence in Japanese patients reported by Hashimoto et al[20] Recently, there was an international, multidisciplinary consensus on the diagnosis and management of patients with FAI syndrome[4]. It was agreed that a diagnosis of FAI syndrome requires not only the presence of abnormal morphology in radiographic studies, but also related symptoms and clinical signs[4]. Therefore, the natural history and treatment of this condition would be different from hip OA with a normal bony morphology[8]. This might warrant the establishment of a specific ICD diagnosis code for FAI syndrome in the future.

The present study showed a lower prevalence (only 3%) of pincer morphology than that reported by other studies[3,10,22]. The explanation would be that the definition of pincer morphology utilized in the current study did not include coxa profunda. Nepple et al showed that coxa profunda was a nonspecific radiographic finding that was found in 76% of asymptomatic subjects, and more frequently in females[23]. Moreover, only 22% of hips with coxa profunda had the radiographic parameters of acetabular over coverage. They concluded that the presence of coxa profunda was not sufficient to support a diagnosis of pincer-type FAI.

Cam morphology is associated with hip OA. A nationwide prospective cohort study of 1,002, early-symptomatic, OA patients by Agricola et al found that 2.76% developed end-stage OA within 5 years, with ORs of 3.67 (95% CI, 1.68 to 8.01) and 9.66 (95% CI, 4.72 to 19.78) for moderate ($\alpha$ angle >60°) and severe cam morphologies ($\alpha$ angle >83°), respectively[8]. Wyles et al studied the natural history and progression of OA hips in patients with hip dysplasia and impingement, with a mean follow-up period of 20 years. They found that degenerative changes were most rapid in patients with developmental dysplasia of the hip, followed by FAI and normal hip morphology. They also found that cam morphology and concomitant acetabular dysplasia were associated with a more rapid progression of OA[7]. In spite of that, pincer morphology was not related to the progression of OA; moreover, it had a protective effect on the development of OA[9]. For that reason, the authors of the present study focused more on the radiographic prevalence of the cam morphology. The authors chose many characteristics of radiographs to detect abnormal cam morphology: a pistol grip deformity; a herniation pit; a triangular index of more than 2-mm; and an alpha angle >55 degrees, either on the AP pelvic view or the cross-table lateral view.

The present study had some limitations. For one thing, lateral radiographs were not available in every case, which might affect the true prevalence of cam morphology. As to patients who had a femoral head-neck prominence only at the anterior part, although the prominence could be identified in lateral radiographs, it could be missed in AP radiographs. Moreover, many subjects presented with severe-degree or end-stage OA, which made it difficult to detect cam morphology and, even more so, pincer morphology. However, the authors used the hospital's picture archiving and communication system to adjust the contrast and sharpness of the radiographs to facilitate identification of the morphology concerned. In the case of doubtful radiographs, the authors classified them in the "indeterminate morphology" group. Finally, the study did not include the detailed medial history or essential physical examinations, and it was unable to evaluate the prevalence of FAI syndrome. According to the Warwick agreement, FAI syndrome should be defined as a triad of symptoms, clinical signs, and imaging findings. Therefore, the present study could provide only the radiographic prevalence of cam or pincer morphology in patients with primary hip OA who underwent THR.

## Conclusion

The present study provided descriptive proportions of the causes of THR in Thai patients during a 15-year study period, and the radiographic prevalence of cam morphology in primary hip OA. Idiopathic AVN was the most common reason for performing THR in the cohort of Thai patients. Moreover, cam morphology was found to be present in at least one-fifth of the Thai patients who had advanced primary hip OA.

## What is already known on this topic?

Many causes of hip OA may lead to a THR, for example, avascular necrosis (AVN) of the femoral head, primary OA, hip dysplasia, and a recently recognized condition of femoroacetabular impingement (FAI). FAI syndrome is defined as a triad of symptoms, clinical signs, and image findings. Cam morphology refers to an abnormal, bony morphology of the femoral head-neck junction, whereas pincer morphology is characterized by either global or focal over coverage of the acetabular rim. Cam morphology is associated with hip OA.

## What this study adds?

The current study provided descriptive proportions of the causes of THR in Thai patients during a 15-year study period, and the radiographic prevalence of cam morphology in primary hip OA. Idiopathic AVN was the most common reason for performing THR in the cohort of Thai patients. AVN due to drugs was the leading cause of THR in the very young age group (<30 years). Moreover, cam morphology was found to be present in at least one-fifth of the Thai patients who had advanced primary hip OA.

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## Potential conflicts of interest

The authors declare no conflicts of interest.

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