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ORIGINAL PAPER

Clinical importance of impingement deformities for hip osteoarthritis progression in a Japanese population

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Abstract
Purpose Femoroacetabular impingement is a new disease concept for hip disorders in young adults suggested as a major cause of primary hip osteoarthritis in Western countries. However, significant controversy exists regarding the prevalence and contribution of impingement deformities to osteoarthritis in Japan, owing to the higher prevalence of developmental dysplasia of the hip. Therefore, the aims of this study were to: (1) determine the prevalence of structural abnormalities associated with hip disorders in patients undergoing total hip replacement and (2) analyse the contribution of impingement deformities to osteoarthritis.
Methods We analysed 250 patients from two different medical centres who underwent primary total hip replacement except those which were due to femoral head necrosis, posttraumatic osteoarthritis and systemic inflammatory disease. The average patient age at surgery was 64 years (range, 40–89 years), with 35 men and 215 women.
Results Radiographic abnormality related to developmental dysplasia of the hip was associated with the majority of osteoarthritic hips (62 %). Hips with femoroacetabular impingement deformities were present within the cases categorized as unknown etiology. Cam impingement deformity was present in 22 % of unknown aetiology cases when cases with reactive osteophytes were excluded from all cam deformity cases (pistol grip deformity and aspherical femoral heads).
Conclusions The prevalence of femoroacetabular impingement within primary osteoarthritis cases and gender predominance of impingement deformities are relatively similar to those reported previously in Western populations. This finding indicates that femoroacetabular impingement deformities are associated with osteoarthritis in the Japanese population, although it has a lower frequency among all hip failure patients.

Keywords Osteoarthritis of the hip · Developmental dysplasia of the hip · Femoroacetabular impingement · Cam impingement · Pincer impingement

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Introduction

Various hip disorders, including osteoarthritis, osteonecrosis of the femoral head, inflammatory arthritis, and posttraumatic conditions, can cause end-stage arthritis. In osteoarthritis, in particular, structural abnormality of the hip can cause disease progression. Thus, early diagnosis and hip-joint preservation surgery has received increased attention [1, 2].

In Japan, developmental dysplasia of the hip is the most common cause of secondary osteoarthritis compared to Western countries [3, 4]. Developmental dysplasia of the hip involves excessive loading of the cartilage, dynamic instability, and muscular fatigue in the hip, resulting in joint degeneration [5]. Contrarily, another concept of anatomical abnormality, femoroacetabular impingement, has recently received attention owing to improved diagnostic methods and innovations in surgical treatment [6–9].

Femoroacetabular impingement is considered a common cause of hip pain in young adults and a pathologic process caused by anatomical abnormality of the acetabulum, femoral head, or both, suggesting that it is a cause of primary hip osteoarthritis [6, 9, 10]. Structural malformations of the acetabular rim (pincer deformities) and the femoral head-neck junction (cam deformities) produce dynamic, repetitive abutment between the proximal femur and the acetabular rim, leading to labral dissociation and articular cartilage degeneration [6, 11].

Currently, there are reports of two main types of femoroacetabular impingement: cam and pincer-type impingement [8]. Cam impingement manifests as a non-spherical portion of the femoral head, usually causing labral and articular cartilage damage, particularly in the anterosuperior section [1, 11]. Pincer impingement typically results from acetabular over-coverage and causes circumstantial damage of the hip joint [6]. In addition, some cases have both impingement types.

Although the role of femoroacetabular impingement in osteoarthritis remains controversial, a recent study involving a Western population has shown the prevalence of radiographic femoroacetabular impingement in younger individuals undergoing total hip replacement [12]. However, the prevalence of femoroacetabular impingement-related hip osteoarthritis among Japanese individuals remains unknown. Thus, we clarified whether femoroacetabular impingement is related to the progression of hip osteoarthritis in Japan by assessing the prevalence of radiographic femoroacetabular impingement in patients who underwent total hip replacement.

Materials and methods

A retrospective search was performed on the patients who were treated with total hip replacement at two medical centres. Total hip replacements were performed from 2007 to 2013, and 250 cases were included in this study. Patients with femoral head necrosis, post-traumatic osteoarthritis, inflammatory arthritis, and other systemic disease cases were excluded. This study protocol was approved by our institutional review boards.

The average patient age at surgery was 64 years (range, 40–89 years), with 35 men and 215 women. All pertinent medical history information and radiographic analysis data of the acetabular and proximal femoral anatomy were used to determine the apparent cause of hip joint failure. The cases were initially classified into broad diagnostic categories, including developmental dysplasia of the hip, Legg-Calve-Perthes disease, slipped capital femoral epiphysis (SCFE), or osteoarthritis with unknown aetiology. Cases that were classified as unknown aetiology were reviewed radiographically to identify femoroacetabular impingement deformities.

For medical record review, outpatient clinic notes, inpatient charts, and operative records were assessed. The earliest radiographs available were assessed, if multiple images existed. To categorize osteoarthritis, anteroposterior pelvic radiographs [13] were measured to obtain the lateral centre-edge angle and the sharp angle. Developmental dysplasia of the hip was diagnosed if the lateral centre-edge angle was <20° and the sharp angle was >45°. In the absence of radiographic features of developmental dysplasia of the hip, Perthes disease, or SCFE, cases were evaluated for the characteristics of impingement deformity. Cam impingement deformity was documented as aspherical femoral heads, defined as pistol grip deformity on anteroposterior radiographs and an alpha angle >50° at the cross lateral projections [13]. Aspherical femoral heads were classified as primary cam deformity or reactive osteophytes due to joint degeneration with the presence of trabecular continuity on plain radiographs and computed tomography (CT) scans. Pincer impingement deformity was identified by the presence of retroverted acetabula, coxa profunda, or coxa protrusio [1, 6, 8]. Acetabular version was characterized by evaluating the presence of acetabular cross-over sign [13]. Coxa profunda was identified if the medial wall of the acetabulum abutted or traversed the ilioischial line [13]. Coxa protrusio was defined as the medial aspect of the femoral head crossing the ilioischial line [13]. Hips exhibiting features of both cam and pincer impingement were considered combined impingement deformities [6]. The radiographs were reviewed by two investigators twice to determine the intra- and inter-observer reliabilities. The intra- and inter-observer reliabilities were evaluated with intraclass correlation coefficient (ICC) for continuous variables. The ICCs for intra- and inter-observer reliability were > 0.85 (range, 0.87–0.97) for all parameters. Based on the observed reliability of the results, evaluations with a single investigator were used in this study.

All data are reported as means and standard deviation for continuous variables and number of cases (and percentage of the group) for categorical variables. When baseline characteristics and radiographic parameters were compared between the different groups separately, chi-square tests were used for categorical variables, and unpaired t tests were used for continuous variables. A p value <0.05 was considered statistically significant.

Results

Etiologies of hip joint degeneration

The diagnosis associated with hip joint degeneration varied; however, developmental dysplasia of the hip was the dominant indication for hip replacement surgery (Table 1). Of the 250 hips, 155 (62.0 %) had developmental dysplasia, 88 (35.2 %) had unknown etiologies, and seven (2.8 %) were classified to other categories such as Legg-Calve-Perthes disease and SCFE. Among women, developmental dysplasia of the hip was twice as common as unknown etiologies, while among men, unknown etiologies were as common ($p<0.05$) as dysplasia. The mean age at total hip replacement surgery for dysplasia cases was 65.7 years in men and 62.9 years in women, and these mean ages were significantly lower than those of both men and women with unknown aetiologies ($p<0.001$).

Table 1 Diagnostic categories and patient characteristics for 250 hips

Diagnosis	Number of hips[a]			Age of patients[b] (year)		
	Female (n=214)	Male (n=36)	Overall (N=250)	Female (n=214)	Male (n=36)	Overall (N=250)
DDH	140 (56.0%)	15 (6.0%)	155 (62.0%)	62.9±10.1	65.7±8.3	63.4±9.6
Unknown	71 (28.4%)	17 (6.8%)	88 (35.2%)	71.3±8.9‡	73.1±8.6[c]	71.6±9.1[c]
Other	3 (1.2%)	4 (1.6%)	7 (2.8%)	68.7±8.1	65.3±8.2	66.7±7.7

[a] The values are expressed as the number and percent of patients

[b] The values are expressed as years of age and the standard deviation

[c] A significant difference (p<0.001) was shown between DDH and unknown etiology within the same gender group

DDH developmental dysplasia of the hip, *unknown* unknown etiology

Radiographic abnormalities associated with unknown aetiology

Detailed radiographic analysis of hip osteoarthritis with unknown etiology demonstrated prevalent structural abnormalities associated with femoroacetabular impingement. Of the 88 hips classified as unknown etiology for cam impingement deformity, 36 (40.9 %) had positive pistol grip deformity, and 62 hips (70.5 %) showed an aspherical femoral head with cross lateral projection. Men showed a higher percentage of pistol grip deformity (11/17) than women (p<0.05). Analysis of the pincer impingement deformity revealed that 15 hips (17.0 %) had crossover sign, and 23 hips (26.1 %) showed coxa profunda. No cases demonstrated the radiographic features of protrusio in this study. The crossover sign was more common in men than in women (p<0.05), while women had a higher percentage of coxa profunda than men (p<0.05).

Presence of primary cam deformity

Radiographic evaluation revealed the presence of "cam-like" deformity among unknown aetiologies cases; however, these cases should include reactive osteophytes at the femoral head neck junction due to intra-articular pathology. Detailed criteria for primary cam deformity and reactive osteophytes have not been established; thus, trabecular bone continuity on CT imaging and configuration of the femoral head neck junction were evaluated for classification in this study. Specifically, a precipitous bump with an asymmetric surface and/or irregular continuity of the trabecular bone at the bump boundary was classified as reactive osteophytes. Of 36 cases with positive pistol grip deformity, 14 (15.9 % of all unknown aetiology cases) had primary pistol grip deformity, and 22 (25.0 %) had reactive osteophytes. Men were more likely to have positive primary pistol grip deformity than women (p<0.01). The mean age at surgery in both in men and women was significantly higher in the positive primary pistol grip deformity cases than the reactive osteophyte cases (p<0.05). An aspherical femoral head was defined as an alpha angle >50° with cross lateral projection. Of the 62 cases analyzed, 17 (19.3 % of all unknown aetiology cases) had a primary aspherical femoral head. The mean age at total hip replacement surgery for men with a primary aspherical femoral head was significantly higher than that in women (p<0.001), but lower than that of men with reactive osteophytes (p<0.001). In this study, we identified primary cam deformity according to its radiographic features with the presence of a positive primary pistol grip and/or aspherical femoral head. A total of 19 cases (21.6 % of all unknown aetiology cases) were classified as primary cam deformity, including seven men (8.0 %) and 12 women (13.6 %).

Discussion

The present study was designed to analyse patients with end-stage hip osteoarthritis who had undergone primary total hip replacement in a Japanese population. The goals of this study were to determine the structural abnormalities associated with hip joint degeneration, especially femoroacetabular impingement deformities. Our data are unique because we focussed on a Japanese population, in which most hip disorders are due to developmental dysplasia, with femoroacetabular impingement deformity, which has been widely reported in Western countries [4, 14].

Our findings demonstrate that developmental dysplasia of the hip is a major cause of end-stage hip osteoarthritis, and a younger mean age at hip replacement surgery of this group than that in cases classified as unknown aetiology indicates that developmental dysplasia of the hip confers predominant structural abnormalities associated with osteoarthritis. These data show the same trend as previous reports describing hip dysplasia in Japanese populations [3, 4]; thus, our case population can be described as having the typical background of

Japanese patients with hip disorders. In our case series, 35 % of hips were classified as unknown aetiology.

A recent investigation of hip structural abnormality associated with osteoarthritis revealed that developmental dysplasia of the hip and femoroacetabular impingement abnormalities are a major cause of secondary osteoarthritis in nearly equal proportions [15]; however, this situation may not be applicable in Japan.

In this study, we investigated the prevalence of femoroacetabular impingement abnormality in end-stage osteoarthritis cases classified as unknown aetiology. Our data indicate that radiographic features of cam impingement (pistol grip deformity and femoral head asphericity) and pincer impingement (crossover sign and coxa profunda) were present in osteoarthritis cases in Japan (Tables 2 and 3). Specifically, a detailed investigation of cam impingement deformity, defined as a positive pistol grip deformity and/or aspherical femoral head, was performed because this study was a retrospective analysis for end-stage osteoarthritis. The definition of primary cam impingement deformity excluded cases of reactive osteophytes and a precipitous bump with an asymmetric surface. Cam impingement deformity was highly prevalent in men (41 % among unknown aetiology male cases), and this trend is completely opposite of the prevalence ratio of developmental dysplasia of the hip. These data suggest that femoroacetabular impingement deformities may be associated with the onset and long-term prognosis of hip osteoarthritis, particularly in men.

Previous reports showed the structural deformities associated with osteoarthritis. Stulberg et al. described 75 cases of idiopathic osteoarthritis in all age groups and identified pistol grip deformity in 40 % and acetabular dysplasia in an additional 39 % of the population [16]. In a prospective study by Tanzer et al. involving 200 consecutive patients undergoing total hip replacement surgery, 125 (62 %) had primary osteoarthritis, and all patients in this subset had pistol grip deformity detected radiographically [17]. Gosvig et al. reported a 71 % and 36.6 % prevalence of hip malformation associated with femoroacetabular impingement within hip osteoarthritis cases in men and women, respectively [18]. Lung et al. investigated the prevalence of radiographic femoroacetabular impingement in a cohort that had undergone total hip replacement for primary osteoarthritis, and 36 % of patients had definite impingement deformity. They also reported a male predominance in cam-type features and a female predominance in pincer-type characteristics [12]. Our data showed a lower prevalence of femoroacetabular impingement radiographic features among all hip osteoarthritis cases than that in these previous reports; however, 22 % of unknown etiology cases showed cam impingement deformities, and the gender distribution associated with impingement deformities was relatively the same even within the Japanese population.

A contrasting theory presented by Resnick suggests that femoroacetabular impingement deformities of the femur are secondary remodeling phenomenon in the hip osteoarthritis [19]. In this study, end-stage osteoarthritis was evaluated, requiring identification of the primary anatomical deformity or osteophyte formation. We used our own criteria of primary cam deformity, defined only as a smooth aspherical femoral head. Although it may be an imperfect method for detecting

Table 2 Radiographic parameters of hips with unknown etiology (88 hips)

Variables	Number of hips[a]			Age of patients[b] (years)		
	Female	Male	Overall	Female	Male	Overall
Pistol grip deformity						
Yes	25 (28.4%)	11 (12.5%)	36 (40.9%)	69.8±8.1	74.4±5.4[c]	71.2±7.6
No	46 (52.3%)	6 (6.8%)	52 (59.1%)	72.0±9.6	70.7±12.9	71.8±9.9
Femoral head sphericity						
Aspherical	49 (55.7%)	13 (14.8%)	62 (70.5%)	71.1±8.5	72.5±9.4	71.4±8.7
Spherical	22 (25.0%)	4 (4.5%)	26 (29.5%)	71.4±10.3	74.8±6.2	71.9±9.8
Crossover sign						
Yes	9 (10.2%)	6 (6.8%)	15 (17.0%)	69.8±11.9	73.7±8.3	71.3±10.4
No	62 (70.5%)	11 (12.5%)	73 (83.0%)	71.4±8.8	72.7±9.1	71.6±8.8
Coxa profunda						
Yes	22 (25.0%)	1 (1.1%)	23 (26.1%)	69±9.3	53	68.3±9.6
No	49 (55.7%)	16 (18.2%)	65 (73.9%)	72.2±9.0	74.3±7.1	72.7±8.6

[a] The values are expressed as the number and percent of patients who were categorized within unknown etiology

[b] The values are expressed as age in years and the standard deviation

[c] A significant difference ($p<0.05$) was shown between males and females in the same radiographic feature

Table 3 Detail evaluations for cam impingement deformities

Variables	Number of hips[a]			Age of patients[b] (years)		
	Female	Male	Overall	Female	Male	Overall
Pistol grip deformity (total 36 hips)						
Primary	6 (6.8%)	8 (9.1%)	14 (15.9%)	74.0±3.8[c]	76.4±4.7[d]	75.8±4.2[d]
Reactive	19 (21.6%)	3 (3.4%)	22 (25.0%)	68.2±8.4	69.0±3.6	68.3±7.9
Alpha angle>50 (total 62 hips)						
Primary	11 (12.5%)	6 (6.8%)	17 (19.3%)	71.4±10.6	77.0±6.2[e]	73.4±9.4
Reactive	38 (43.2%)	7 (8.0%)	45 (51.1%)	71.1±8.8	80.2±10.3	70.8±9.0
Cam impingement (primary pistol grip deformity and/or alpha angle>50)[f]						
	12 (13.6%)	7 (8.0%)	19 (21.6%)	71.5±10.1	76.6±5.7	73.4±8.9

[a] The values are expressed as the number and percent of patients who were categorized with positive radiographic parameters

[b] The values are expressed as age in years and the standard deviation

[c] A significant difference ($p<0.001$) was shown between primary deformity and reactive osteophyte within males

[d] A significant difference ($p<0.05$) was shown between primary deformity and reactive osteophyte within the same gender group

[e] A significant difference ($p<0.001$) was shown between primary deformity and reactive osteophyte among males, and between males and females within primary deformity

[f] The percentage of patients with an unknown etiology (88 hips)

primary cam deformity in osteoarthritis, our method can avoid mistaken inclusion of cases with reactive osteophyte. Thus, the prevalence of hip impingement deformities, especially cam deformities, may be >22 % in our primary osteoarthritis series.

Although the present investigation presents unique data on a specific group of Japanese patients with end-stage hip osteoarthritis, our study has weaknesses. First, the patients' hip disorders progressed over a long time interval, and the aetiology of end-stage bony appearance may vary during this time frame. For example, even after classification of developmental dysplasia of the hip using plain radiographs, some of the unknown aetiology cases showed disease progression due to hip instability. Second, the radiographic protocols and quality of radiographs varied over the course of the study. We evaluated data from all radiographs with adequate positioning and image quality, but the dataset is imperfect in that all cases did not have the same radiograph quality. Additionally, inadequate visualization of bony landmarks due to secondary osteoarthritic changes occurred on some images. For pincer deformities in particular, osteophyte and/or labrum calcification at the acetabular rim make precise evaluation difficult, and it is impossible to describe the primary pincer deformities in this case series. Finally, it should be noted that our data present the prevalence of radiographic features in end-stage osteoarthritis in a Japanese population and do not present evidence of a perfect cause-and-effect relationship between structural deformities and disease progression.

A previous report indicates that femoroacetabular impingement abnormality is not common in the Japanese population. Takeyama et al. showed that only 1.8 % of hip failure patients who undergo total hip replacement or joint preservation surgeries (acetabular osteotomy, femoral osteotomy, arthroscopic debridement, and others) are evaluated for primary osteoarthritis, and only 0.6 % of patients have femoroacetabular impingement [20]. Our findings also suggest that the prevalence of femoroacetabular impingement in all hip failure patients is lower than that reported for Western countries. However, our data also show that the prevalence among primary osteoarthritis patients and gender predominance of femoroacetabular impingement are relatively similar to those reported previously, indicating that femoroacetabular impingement deformities are associated with osteoarthritis in the Japanese population despite the lower frequency among all hip failure patients.

The number of hip arthroscopy cases is increasing as the concept of impingement and/or labrum tear of the hip joint becomes more widely known [21]. However, it is also true that hip instability, including mild dysplasia, can cause labrum tears like femoroacetabular impingement [22], with clinical symptoms that are relatively the same as those of impingement hips [23, 24]. Hip arthroscopic procedures for these cases may induce further hip instability, thus defeating the purpose of hip preservation surgery [25]. Therefore, investigations aimed at enhancing early diagnosis of impingement and/or instability of the hip and analysing joint preservation treatments are needed to prevent the progression of osteoarthritis.

Conflict of interest The authors declare that they have no conflict of interest.

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