Radiographic factors associated with hip osteoarthritis: a systematic review

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ABSTRACT

The purpose of this study was to outline factors that contribute to the appearance of hip osteoarthritis (OA). Secondarily, this study aims to describe radiographic factors that are associated with the progression of OA in the arthritic hip. Pubmed/MEDLINE and Embase were searched in November 2018 for radiographic risk factors for hip OA. All articles were eligible if they (i) were written in the English language and (ii) commented on OA as it relates to radiographic description, appearance or progression of OA. Demographic characteristics of the study cohort, definition of OA, baseline OA and factors for prediction or progression of OA were recorded. Nine articles were included in this review. A total of 3268 patients were analyzed across all studies. The mean age was 60.0 years (range 18–91.5). The most common descriptors for OA were dysplasia and cam impingement. Six of the nine articles found acetabular under-coverage to be associated with developing OA. Four articles found cam morphology to be an associated factor. Finally, four articles commented on the factors associated with the progression to more severe grades of OA, reporting exclusively on acetabular under-coverage, whereas only one reported on cam morphology to be associated. This systematic review found acetabular under-coverage followed by cam morphology to be strongly associated with both the development and progression of hip OA. These findings define patients at risk for developing hip OA and emphasize the importance of early awareness of future joint degeneration.

INTRODUCTION

Since its introduction nearly nine decades ago, hip arthroscopy has evolved to treat a large array of intra- and extra-articular pathologies [1–4]. A large body of literature evinces the success of hip arthroscopy in treating non-arthritic hip pain [5]. The outcomes of hip arthroscopy, however, have been shown to be inversely related to the level of arthritis [6]. Thus, the ability to identify morphologic risk factors for hip osteoarthritis (OA) may lead to optimized and more detailed consideration for management of this patient population [7–11]. Outlining the connection between hip joint morphology and future OA is a challenging task [2]. The most readily available tool for assessing morphologic features is radiography. Currently, the most common radiographic metrics to grade OA are the Tonnis and Kellgren and Lawrence (KL) classifications [12]. The population graded 0 by either classification is a heterogenic population; some possess features that increase their likelihood of developing OA, while others will simply not develop the disease. The primary goal of this study was to outline the radiographic features that are associated with the development of hip OA. The secondary aim was to describe the radiographic features of the arthritic hip that are associated with the progression of OA once it has developed.
MATERIALS AND METHODS

Article search
Pubmed/MEDLINE and Embase were searched for radiographic risk factors for hip OA. The search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. The following search was performed: (((Risk Factors[Mesh]) AND (Osteoarthritis[Mesh])) OR ‘Osteoarthritis, Hip’ [Mesh])) AND (((X-Rays[Mesh]) OR ‘Radiography’ [Mesh]) OR ‘Tomography, X-Ray Computed’[Mesh]) OR ‘diagnostic imaging’ [Subheading]) AND ((‘Hip’ [Mesh]) OR ‘Hip Joint’[Mesh]).

Two reviewers (BGD and JS) independently reviewed the titles and abstracts to select for full-text review. Both reviewers then examined the full-text articles for eligibility. All articles were eligible if they (i) were written in the English language and (ii) investigated the associations between radiographic structural measurements and OA, as indicated through a radiographic classification. Review articles, techniques articles, case reports, opinions or studies that contained fewer than 10 patients were excluded. Non-English articles were excluded to avoid misinterpretation and optimize data extraction. According to previous literature, English-based language restrictions does not bias a systematic review [13]. Differences in opinion were resolved by reading the articles independently and together to ensure that the studies met the inclusion and exclusion criteria. A study was included if both reviewers came to a consensus that it met the eligibility criteria.

A total of 180 records were found by database search, 22 of which were considered for full-text review. Nine articles were included into this review. Agreement was measured using Cohen’s kappa [14]. There was substantial agreement between the reviewers during the titles, abstracts and full-text selection stages (k > 0.85). The flow chart for article selection is presented in Fig. 1, i.e. full-text review of the chosen articles extracted article information (author, year, study type, level of evidence), demographic characteristics of the study cohort, definition of OA, baseline OA of the cohort and factors associated with the development or progression of OA.

Quality assessment
Quality was assessed by assigning the validated Methodological Index for Non-randomized Studies (MINORS) criteria to each study. Risk of bias was assessed utilizing the Prediction Model Risk of Bias Assessment Tool (PROBAST) to classify the risk of bias. A consensus was reached on any differences during the assessment processes. Most of the included studies were non-randomized, longitudinal studies with control studies. Table 1 presents the MINOR scores with control studies.

RESULTS

Demographics and descriptors
Across 9 articles [15–23], a total of 3268 patients were analyzed. The mean age was 60.0 years (range 18–91.5). Furthermore, the average follow-up time was 11.7 years across all studies. Six of these articles [15, 16, 19–22] were longitudinal studies with follow-up time ranging between 3 and 20 years. In order to define OA, four articles [15, 16, 20, 21] used the KL classification of OA, two [22, 23] studies used the Tonnis classification, three [17, 18, 20] articles defined OA using joint space and one [19] study defined OA as the conversion to total hip arthroplasty (THA). Table I summarizes each study’s specific demographics and respective definition of OA. Furthermore, Table II reports the articles’ specific descriptions of OA.

PROBAST assessment for risk of bias concluded that, given the lack of external validation, all studies demonstrated a high risk of bias.

Predictors and thresholds

Acetabular coverage
Six articles [15, 16, 19–22] constructed models that intended to study factors associated with the development of OA or the development of end-stage OA, defined as the conversion to THA. All these articles measured acetabular under-coverage through Wiberg’s definition [24, 25]. Furthermore, all six articles associated acetabular under-coverage with the development of OA. Bouyer et al. [15] attributed a smaller lateral center edge angle (LCEA) to the appearance of both acetabular and femoral head osteophytes after 3-year follow-up. Castaño-Betancourt et al. [16] found that a smaller LCEA was a risk factor for incident OA, especially for patients who were classified as KL = 0 at baseline (OR = 0.44 for KL = 0 and OR = 0.74 for KL = 1). Furthermore, spherical sector (SS) among patients with baseline KL = 1 was a risk factor for incident OA (OR = 0.93 for KL = 0 and OR = 1.33 for KL = 1). Reijman et al. [20] found that each degree of LCEA below the threshold of 25° increased the odds of developing OA [OR = 4.3 CI = (2.2–8.7)]. On the other hand, Thomas et al. [21] found that the odds of developing OA was reduced per degree above 28° [OR = 0.87; CI = (0.78–0.96)]. Evaluating associations with end-stage OA, Bouyer et al. [15], Nicholls et al. [19] and Wyles et al. [22] found that smaller LCEA was strongly associated with the conversion to THA.
Other authors reached similar findings with different measures of acetabular coverage. Bouyer et al. [15] and Nicholls et al. [19] measured acetabular coverage using the acetabular index, as defined by Bouttier et al. [26] and Murphy et al. [27], respectively. Both these articles found that less coverage was associated with incident OA. Nicholls et al. [19] corroborated this finding with the extrusion index (EI). These findings, along with others, are reported in Table III.

Cam morphology

Four articles [16, 18, 19, 21] included some measure of cam as being associated with developing OA. Among the measurements, alpha angle (AA) [28, 29] and triangular index (TI) [29] were the two most mentioned associated variables. Doherty et al. [18] reported on cam in terms of pistol-grip deformity [30]. While most of these studies reported the findings of OA of the afflicted hip, Nicholls et al. [19] also included an assessment of the contralateral joint. Not only did OA patients have a higher prevalence of pistol-grip deformities, but the unaffected side was also more likely to have pistol-grip deformity as well (OR = 2.72; 95% CI = 1.68–4.41).

Prediction of progression and severity

Acetabular coverage

Four articles [15, 20–22] commented on the factors associated with the progression to more severe grades of OA. All articles exclusively reported less coverage of the acetabulum as the prominent risk factor for developing more severe OA (Table IV).

Cam morphology

While most authors found acetabular coverage as being associated with OA, Thomas et al. [21] described AA as a factor that increased the risk of developing end-stage OA. Specifically, every degree beyond 65° was associated with an increased odd of undergoing THA at the end of the 20-year follow-up period (OR = 1.02; 95% CI = 1.00–1.07).

DISCUSSION

Primary hip joint OA has previously been perceived as idiopathic [31]. However, the findings from the present study suggest that various morphologic variations are associated with an increased risk of future OA [32]. Hip preservation outcomes, by either open or arthroscopic means, may be tempered by OA [33]. Therefore, it is critical to
### Table I. Study demographics

| Authors                  | Year | Study design | 1.s | PROBAST risk of bias rating | LOE | Population   | No. patients | No. hips | Mean age years (range) | Follow-up years (range) | Definition of OA                        | Baseline OA                  |
|--------------------------|------|--------------|-----|----------------------------|-----|--------------|--------------|----------|------------------------|-------------------------------|--------------------------------------|-----------------------------|
| Bouyer et al. [15]       | 2015 | Longitudinal | 15  | High risk                  | 4   | France (KHOALA) | 242          | 484      | 62 (57–68)             | 3                             | KL                                   | KL ≥ 2 one hip or knee           |
| Castaño-Betancourt et al. [16] | 2013 | Longitudinal | 14  | High risk                  | 4   | The Netherlands (Rotterdam) | 119          | 132      | 68 (66.3–69.7)         | 6.5 & 11                       | KL                                   | KL = 0                      |
| Chung et al. [17]        | 2010 | Cross-sectional | 12  | High risk                  | 4   | Korea        | 674          |          | 71.7 (51.9–91.5)       |                              | JSW < 2.0 mm ≤ 2.5 mm           |
| Doherty et al. [18]      | 2008 | Cross-sectional | 22  | High risk                  | 3   | UK           | 965          | 965      | 67.7 (46.4–89)         |                              | J SW ≤ 2.5 mm                      |
| Nicholls et al. [19]     | 2011 | Longitudinal | 24  | High risk                  | 3   | UK (Chingford) | 135          | 268      | 55 (50–60)             | 20                            | End-stage OA marked by THA      |
| Reijman et al. [20]      | 2005 | Longitudinal | 23  | High risk                  | 3   | The Netherlands (Rotterdam) | 835          | 835      | 68.2 (48.4–88)         | 6.6                           | JS ≤ 1.0 mm                        | KL < 2; JSN ≥ 1.0 mm               |
| Thomas et al. [21]       | 2014 | Longitudinal | 23  | High risk                  | 3   | UK (Chingford) | 70           |          | 54.2 (44–67)           | 20                            | KL                                   | KL < 2; no THA                  |
| Wyles et al. [22]        | 2017 | Longitudinal | 24  | High risk                  | 3   | USA          | 162          | 162      | 47 (18–55)             | 20 (10–35)                     | Tonnis = 0, contralateral THA   |
| Zeng et al. [23]         | 2016 | Cross-sectional | 13  | High risk                  | 3   | China        | 66           | 132      | 37.5 (21–49)           |                              | Tonnis                              |

AA, alpha angle; AD, acetabular depth; AI, acetabular index; EI, extrusion index; FH, femoral head; JSN, joint space narrowing; JSW, joint space width; KL, Kellgrean and Lawrence; LCEA, lateral center edge angle; SS, spherical sector; THA, total hip arthroplasty.
identify patients who are at risk but have not yet developed OA to optimize their treatment outcomes. This study aimed to determine which radiographic features are associated with the development of future OA. Nine reviewed articles [15–23] discussed radiographic measures in the context of prediction or progression of hip OA. Eight articles [15–17, 19–23] found a positive association between acetabular under-coverage and OA. Five articles [16, 18, 19, 21, 23] found a positive association between cam impingement and OA.

Six articles [15, 16, 19–22] constructed regression models that predicted the development of OA based on longitudinal follow-ups of non-arthritic patients who eventually developed OA. Kim et al. [34] compared radiographic JSW with the articular cartilage signal measured by delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) in patients with hip dysplasia. The authors found that lower dGEMRIC indices portended early arthritic changes and correlated inversely with the severity of dysplasia as measured by LCEA (r = 0.52, P < 0.001). In line with Kim et al. [34], six articles [15, 16, 19–22] found dysplasia as associated with the development of OA. Furthermore, Nicholls et al. found acetabular under-coverage to be associated with total hip replacement

Table II. Description of osteoarthritis

| Authors          | Acetabular measurements | Femoral measurements |
|------------------|-------------------------|----------------------|
| Chung et al. [17]| LCEA<30: OR of OA=10.2 (1.8–56.7)<sup>a</sup> OR of OA=21.0 (0.6–788.0)<sup>b</sup> | LCEA<40 OR of OA=1.9 (0.6–6.2)<sup>a</sup> = 2.2 (1.5–3.2) 2.3 (1.5–3.4)<sup>b</sup> |
| Doherty et al. [18] | LCEA<20° 11.31% versus 0.81% | Pistol-grip deformity 3.61% versus 17.71%, OR=6.95; 95% CI=4.64–10.41 Femoral head–neck ratio: <1.27 is 3.70% versus 24.27%, OR = 10.45 (7.16–15.24) |
| Nicholls et al. [19] | LCEA: 29.54° ± 7.68° versus 34.32° ± 6.77° P=0.001 El: 0.25 versus 0.185 P = 0.009 Al: 5.32° (2.74°–10.83°) versus 4.125° (2.4°–6.39°) P = 0.013 | AA: 45.75° (43.29°–53.95°) versus 62.5° (46.52°–83.6°), P = 0.001 |
| Reijman et al. [20] | LCEA<30: 17.9% versus 31.0% LCEA<25: 3.8% versus 12.6% AD<9 mm: 10.7% versus 23.0% | |
| Thomas et al. [21] | LCEA: 30.03° ± 8.11° versus 30.56° ± 6.44°, P-value=0.456 | AA: 46.47° (45.53°–55.23°) versus 55.81° (44.09°–87.60°) P<0.001 (mean, IQR); Ti: 22.90 (SD=2.90) versus 23.67 (2.52) P<0.001 |
| Zeng et al. [23] | Al: (male) 36.21° ± 3.62° versus 38.22° ± 3.62°, P <0.001 (female): 34.36 ± 3.62° versus 37.09 ± 3.69°, P <0.001 | AA: (male) 39.61 ± 2.56° versus 41.42 ± 2.51°, P<0.001 (female) 38.77 ± 2.27° versus 40.46 ± 1.52°, P<0.001 |
|                  | LCEA: (male): 31.67 ± 6.42° versus 33.53 ± 5.08°, P=0.036 (female): 28.91 ± 6.72° versus 31.13 ± 5.63°, P=0.037 | |

For all comparative measurements the non-OA is presented followed by OA; mean ± standard deviation or mean (interquartile range).

<sup>a</sup>OA is defined as JS < 2.5 mm.
<sup>b</sup>OA defined as JS < 2.0 mm.
AA, alpha angle; AI, acetabular index; JS, joint space; LCEA, lateral center edge angle, SD, standard deviation.
### Table III. Radiographic predictors for developing osteoarthritis

| Authors               | Acetabular coverage predictions                                                                 | CAM predictions                                                                 |
|-----------------------|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Bouyer et al. [15]    | AI: AI $> 7$ (per degree) was positively associated with multiple radiographical features.      |                                                                                  |
|                       | With JSN OR $= 1.05$ (1.00–1.10),                                                                 |                                                                                  |
|                       | Osteophytes at 6 different locations OR ranges $1.05–1.15$                                      |                                                                                  |
|                       | LCEA: associated with subchondral bone condensation OR $= 0.97$ (0.94–0.99)                      |                                                                                  |
| Castaño-Betancourt et al. [16] | LCEA: (baseline KL $= 0$) OR of incident OA $0.44$ (0.26–0.73);                                 | TI: (baseline KL $= 0$) OR $= 1.26$ (0.6–2.62) (baseline KL $= 1$) OR $= 1.69$ (1.32–2.17) |
|                       | (baseline KL $= 1$) OR $= 0.74$ (0.59–0.93)                                                      |                                                                                  |
|                       | SS: (baseline KL $= 1$) OR $= 1.33$ (1.07–1.64)                                                  |                                                                                  |
| Doherty et al. [18]   |                                                                                  |                                                                                  |
|                       | LCEA: decreased odds (per degree) for THA OR $= 0.887–0.906^a$                                  | AA: increase odds (per degree) for THA OR $= 1.121–1.131^a$                      |
|                       | AI: increased odds (per degree) for THA OR $= 1.242–1.306^a$                                   | TI: increased odds for THA OR $= 1.149–1.306^a$                                  |
|                       | El: associated with progression to THA (OR $= 1.056$–1.064).                                    |                                                                                  |
| Nicholls et al. [19]  |                                                                                  |                                                                                  |
|                       | LCEA: LCEA $< 30$ developing OA (adjusted OR $= 1.7$, 1.2–2.5). LCEA $< 20^a$, the OR was 2.4 (1.2–4.7) | AA: AA $> 65^a$ associated with increase odds of developing OA OR $= 1.05$ (1.01–1.09) |
|                       | AD: AD $< 9$ mm developing OA, OR (adjusted 2.3, 1.5–3.5).                                       |                                                                                  |
| Reijman et al. [20]   |                                                                                  |                                                                                  |
|                       | LCEA: LCEA $< 28^a$ increased the risk of developing OA (OR $= 0.87$, 0.78–0.96)               |                                                                                  |
|                       | El: OR $1.15$ (0.77–1.77), $P = 0.508$                                                          |                                                                                  |
| Thomas et al. [21]    |                                                                                  |                                                                                  |
|                       | LCEA: LCEA $< 25^a$ HR $= 2.9$ (1.2–6.5)                                                        |                                                                                  |
|                       | $P = 0.013$ for Tonnis 0–3, HR $= 1.4$ (0.8–2.4) $P = 0.265$ for Tonnis 0–2, HR $= 1.4$ (0.9–2.0) $P = 0.155$ for Tonnis 0–1 |
| Wyles et al. [22]     |                                                                                  |                                                                                  |

$^a$Depending on covariates selected for.

AA, alpha angle; AI, acetabular index; AD, acetabular depth; EI, extrusion index; JSN, joint space narrowing; LCEA, lateral center edge angle; TI, Triangular Index; HR, hazard ratio; OR, odds ratio; THA, total hip arthroplasty.
in a longitudinal study with a follow-up period of 20 years [19]. Out of these studies, Chung et al. found a strong association between dysplasia indicated by LCEA < 30 and LCEA < 40 and OA of the hip (OR = 10.2 and 1.9, respectively) when JSW was under 2 mm [17]. Furthermore, Reijman et al. found a strong association between dysplasia, indicated by LCEA < 20 and acetabular depth < 9 mm and OA < 1.0 mm with OR 2.8 (95% CI = 1.8–4.5).

Last, strong association was demonstrated by Thomas et al. regarding dysplasia, indicated by EI and OA of the hip (OR = 2.50) [21].

Reichenbach et al. [35] examined the associations of cam morphology with labral lesions and cartilage damage in 244 asymptomatic men (mean age =19.9 years). An MRI analysis found that the adjusted mean difference in combined anterosuperior femoral and acetabular cartilage thickness was −0.19 mm (95% CI = −0.41 to 0.02) in men with cam deformities, as measured by head–neck offset on MRI, compared with those without. With respect to Reichenbach’s study [35], the present study reviewed four articles [16, 18, 19, 21] analyzing the associations between the presence of a cam lesion and developing OA. Ishøi et al. investigated the association between demographic and radiographic factors and intra-articular chondral damage of the hip [36]. Overall 1511 patients were included in the study. Hip joint cartilage injury was identified and documented intraoperatively during hip arthroscopy. The authors found that increased AA was associated with damage of the articular cartilage (OR = 2.23 for 78° < AA ≥ 55° and OR = 4.82 for AA > 78°). Additionally, the authors found that borderline dysplasia was also associated with intra-articular cartilage damage (OR = 3.08). They concluded that increased severity of the cam morphology, concurrent with borderline dysplasia, substantially increased the risk of moderate to severe hip joint cartilage damage.

Corroborating with Ishøi et al. six of the nine studies [15, 20–22, 28, 29] evaluated morphologic parameters that

| Authors              | Acetabular coverage progression                                      | CAM                                      |
|----------------------|-----------------------------------------------------------------------|------------------------------------------|
| Bouyer et al. [15]   | AI: AI>7° (per degree) increased the presence of osteophytes at 3 years OR = 1.05–1.19°, HR = 1.18 (1.07–1.29) for undergoing THA | LCEA: associated with appearance of medial osteophytes OR = 0.92 (0.88–0.98) |
| Reijman et al. [20]  | LCEA: LCEA<30° OR = 2.8 (1.9–4.2) for JSN ≥ 1 mm. LCEA < 25°, OR = 4.3 (2.2–8.7). AD<9 mm was identified to be risk factors for JSN ≥ 1.0 mm with OR 2.8 (95% CI = 1.8–4.5). |
| Thomas et al. [21]   | EI: every standard deviation of EI increased odds of undergoing THA OR = 2.50 (1.78–3.48, P ≤ 0.001). | AA: AA>65° (per degree) increased odds of developing end-stage OA OR = 1.02 (1.00–1.07), P = 0.082 |
| Wyles et al. [22]    | LCEA: every 10° increase HR 0.7, (0.5–1.0), P = 0.072 for Tonnis Grade 0 to Tonnis 3, HR = 0.8 (0.6–1.0), P = 0.036 for Grade 0 to Tonnis 3 or THA | AI: Every 10° increase HR = 1.7 (1.1–2.5) P = 0.019 for Tonnis 0–3, HR = 1.6 (1.1–2.3) P = 0.007 for Tonnis 0–3 or THA |
|                      | AD: Per 0.1 increase HR = 0.4 (0.2–0.8) for Tonnis 0–3, HR = 0.01, OR = 0.5 (0.3–0.8) P = 0.007 for Tonnis 0–3 or THA |                      |

*Depending on covariates selected for.

AA, alpha angle; AD, acetabular depth; AI, acetabular index; EI, extrusion index; JSN, joint space narrowing; LCEA, lateral center edge angle; TI, Triangular Index; HR, hazard ratio; OR, odds ratio; THA, total hip arthroplasty.
are associated and OA. They found that cam lesion as defined by AA, TI and a radiographic description of pistol-grip deformity is associated with radiographic OA. Out of these studies, Doherty et al. found a strong association between cam deformity, as indicated by pistol-grip deformity and femoral head–neck deformity and OA of the hip (OR = 6.95 and 10.45, respectively) [18].

Troelsen et al. [37] assessed the medium-term outcome following periacetabular osteotomy (PAO). One hundred and sixteen patients who had undergone PAOs performed by the senior author were followed-up at a mean of 6.8 years. When adjusting for preoperative OA, severe dysplasia (LCEA <25) was associated with the conversion to THA. Coinciding with Troelsen et al. four articles [15, 20–22] in this systematic review commented on the progression to more severe levels of OA. All exclusively reported less coverage of the acetabulum [15, 20–22] as the chief risk factor for the progression to more severe levels of OA.

Gregory et al. [38] used active shape models to determine whether morphologic variability of the proximal femur could be quantified as a marker of hip OA. Their study design included 110 subjects who were at least 55 years of age and had no signs of radiographic OA (KL < 2). At 6-year follow-up, 55 subjects had established OA (KL = 3), 12 of whom required THAs. Morphologically, subjects with less pronounced curve of the upper femoral neck into the head, resembling cam lesion at baseline, were more likely to develop OA [OR = 1.62 (1.08–2.45), P = 0.020]. Patients that underwent THA had even more pronounced cam lesions at baseline [OR = 2.35 (1.15–4.82), P = 0.019], further suggesting that a cam lesion is associated with the progression of established OA to end-stage OA. In this systematic review, one article [21] found that patients with AA > 65° had increased risk of developing end-stage OA.

In summary, risk for developing hip OA, as well as risk for OA progression, can be assessed radiographically. Being attentive to these radiographic parameters as potential risk factors will help the clinician and patient prognosticate outcomes and develop a structured, evidence-based treatment plan that will provide symptomatic relief and, hopefully, limit future joint degeneration.

Strengths
The strengths of this systematic review include its comprehensive description of radiographic factors associated with the development and progression of OA. Although there were no randomized controlled studies included, the articles used in this systematic review scored high on the MINORS criteria.

Limitations
Predictive factors are best demonstrated with longitudinal studies, which trace non-affected hips without OA until a subset of the cohort develops the disease. Three of the studies were cross-sectional [17, 18, 23]. Moreover, after the assessment for risk of bias using PROBAST, all of the reviewed studies showed high risk of bias due to a lack of external validation. Hence, rather than reporting predictive factors of OA, these studies demonstrate associations between radiographic morphology and OA. Doherty et al. [18] sought to mitigate this drawback by comparing the arthritic hip to the contralateral non-arthritic hip. Furthermore, limitations exist even among longitudinal studies. One study [19] compared patients who underwent THA at the end of the follow-up period with patients who did not. The authors did not report on the baseline level of OA of the population that did not undergo THA, which does not allow the reader to conclude which factors within pre-existing arthritic hips increase the likelihood of OA progression. Lastly, although this study showed certain radiographic parameters are associated with the development and progression of OA, it cannot state that treating these pathologies via means of hip preservation would ultimately prevent end-stage disease.

CONCLUSION
This systematic review demonstrated that acetabular under-coverage and cam morphology are associated with the development and progression of hip OA. These findings help define patients at risk for developing hip OA, emphasize the importance of early diagnosis for this population and play a role in the possible prevention of future joint degeneration.

CONFLICT OF INTEREST STATEMENT
None declared.

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