

Pediatric Radiology

Does presence of hip dysplasia affect the prevalence and location of cam morphologies in pediatric hip pain patients?



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ABSTRACT

Background: Hip dysplasia and cam morphology are both common causes of hip pain in pediatric patients. However, there is limited literature on how the presence of hip dysplasia may affect the prevalence of cam morphology.

Objective: This study aims to assess if hip dysplasia in pediatric patients has a similar prevalence and location of cam morphology compared with non-dysplastic hips.

Materials and methods: This retrospective study assessed pediatric patients with hip pain from April 2012 to June 2024. Data collection was based on chart review and imaging consensus review of all hip MRIs conducted by two musculoskeletal radiologists and a pediatric orthopedic surgeon. Data included were the presence of hip dysplasia, defined as a lateral center-edge angle (LCEA) $<18^\circ$, cam morphology, and their location. Chi-square and Fisher's exact test were used with p -values for significance set to 0.05.

Results: From our study cohort of 118 hips in 107 patients (mean age 15.3 years, 66% female, 81 hips underwent surgery), there were 64 cam morphology hips present. Cam morphology was present in 55.6% of dysplastic hips and 53.7% of non-dysplastic hips ($p = 0.849$). Cam morphology was most commonly located anterosuperior femoral head-neck in 70% of dysplastic hips and 65.9% in non-dysplastic hips ($p = 0.747$).

Conclusion: Cam morphology is frequently identified in pediatric patients with hip pain. The prevalence and location of cam morphology is not affected by the presence of co-existing hip dysplasia. During imaging work-up and treatment planning, it is important to recognize that a high proportion of pediatric hip dysplasia patients may have a co-existing cam morphology.

1. Introduction

Two common causes of pediatric hip pain include femoroacetabular impingement syndrome (FAI) and hip dysplasia. FAI is a condition caused by irregular hip architecture that leads to abnormal contact between the femur and acetabulum, most commonly in flexion and rotation. FAI can be classified as either pincer-type or cam morphology, with a mixed type of both cam morphology and pincer-type being the most common.¹⁻³ The prevalence of cam morphology in asymptomatic volunteers is 55% in athletes and 23% in non-athletes.⁴ However, it can also be symptomatic and the only cause of hip pain in patients. When present, cam morphology is a bony prominence at the femoral head/neck junction that causes loss of the femoral head sphericity. Cam

morphology is more common in adolescent athletes and may predispose the patient to labral tears, chondral injuries, subsequent early osteoarthritis; however, it can independently be symptomatic and the sole reason for hip pain.^{3,4} Hip dysplasia is defined as under-coverage of the femoral head by the acetabulum and is quantified radiographically by measuring the LCEA. This leads to acetabular edge loading and hip instability. Dysplasia can lead to labral tears, chondral injury, and early-onset osteoarthritis.⁵⁻⁷ The prevalence of hip dysplasia has been shown to be 8.2% in patients with hip pain.⁸

Although there is extensive literature on both FAI and hip dysplasia independently, there is limited literature on the coexisting relationship of FAI and hip dysplasia in the pediatric population. It remains unclear how often these two entities coexist. Additionally, when they do co-

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exist, it is unclear whether the nature and location of a cam morphology affects patient treatment. Both conditions have been attributed to cause labral tears, with one meta-analysis identifying labral tears in 78.8% in patients with hip dysplasia and 93.8% in patients with FAI.⁹ Previous studies about outcomes of periacetabular osteotomy surgery for hip dysplasia have shown that subsequent hip arthroscopy may be required for untreated FAI.^{10,11} Understanding the relationship between FAI and hip dysplasia and at what rate they co-exist would be useful to the physician in assessing the pathophysiology of the hip and deciding treatment recommendations and intra-operative decision making. To our knowledge, no study has assessed the relationship between pediatric hip dysplasia and cam-type FAI morphology and their impact on surgical treatment.

The purpose of this study is to assess if pediatric patients with hip dysplasia (LCEA < 18 degrees) has a similar prevalence of cam morphology compared with non-dysplastic hips, and whether the location of the cam morphology is different in dysplastic and non-dysplastic hips.

2. Methods

After institutional review board approval, a retrospective electronic medical record query was performed via a radiology search tool (PowerScribe Workflow Orchestration, Nuance Communications, Burlington, Mass) to identify patients who had hip pain, an MRI of the hip, radiographs of the pelvis, and a clinical assessment by our pediatric tertiary care hip preservation clinic between April 2012 to June 2024. Patients were excluded if they were older than 18 years of age at the time of MRI, had a previously diagnosed condition that directly or indirectly may predispose them to neuromuscular hip dysplasia (e.g., cerebral palsy), a previously diagnosed condition that can cause avascular necrosis of the hip (e.g., Perthes disease, slipped capital femoral epiphysis), a previously diagnosed condition that could cause decreased bone density (e.g., osteogenesis imperfecta) or bone deformity (e.g., tumors of the bone), or had prior hip surgery or closed/open reduction of the ipsilateral hip that was being studied.

Our initial search yielded 390 patients. Of these, 86 were excluded because the patient was >18 years of age at time of hip MRI, 27 were excluded due to neuromuscular hip dysplasia, 89 were excluded due to avascular necrosis of the hip as a secondary process from a co-existing medical diagnosis, 24 were excluded due to past medical diagnosis of diseases that cause reduced bone density or cause bone deformity, and 57 were excluded due to previous hip surgery or previous open/closed reduction of the hip. After these exclusions, 107 patients (118 hips) constituted our study cohort.

2.1. Imaging data collection

Two musculoskeletal radiology faculty, one with 20 years of

experience and one with 8 years of experience, and one pediatric orthopedic faculty with 18 years of experience, performed a consensus review of the dedicated hip MRIs with knowledge of the official radiology report to determine the presence/absence of cam morphology based on MRI. It is quantified alpha angle measurement of 55 degrees or greater based on radial MRI sequences, due to previous studies showing that having a cutoff of 55 degrees has a 81–90% sensitivity rate in diagnosing FAI.¹² The highest alpha angle was used for binomially diagnosing the presence of cam morphology based on MRI. Location was subcategorized whether it was located anterior, anterosuperior, superior, posterosuperior, or diffuse as well as if it involved the femoral epiphysis or metaphysis. Diffuse involvement was defined by cam morphology involving >50% of the circumference. Epiphyseal or metaphyseal cam morphology is defined by where the location of the maximal offset is located cranial (Fig. 1) or caudal (Fig. 2) with respect to the open physis or closed physis/physeal scar. LCEA was determined on the presentation standing AP pelvis radiographs, and data was collected from medical records, or was calculated if the LCEA was not available. LCEA measurement was performed with reference to the lateral edge of the sclerotic acetabular sourcil. Patients were binomially categorized with (LCEA < 18 degrees) or without (LCEA 18 degrees or above) co-existing hip dysplasia. MRI and X-ray were collected within 18 months of one another.

2.2. Surgical data collection

The electronic health record (Epic, Verona, WI) was queried of all 107 patients included in the study cohort to determine if they underwent surgical treatment. Data points included type of surgery such as a periacetabular osteotomy (PAO) to treat hip dysplasia and/or femoral osteochondroplasty to treat the cam morphology if performed.

2.3. Statistics

All statistical analyses were conducted with IBM SPSS Statistics, version 29.0 (Armonk, NY: IBM Corp). Chi-square tests and Fisher's exact were used for analyzing categorical data including cam morphology location, cam morphology type, and presence of hip dysplasia as appropriate. All tests were two-sided with a *p*-value significance set to 0.05.

3. Results

From our study cohort of 118 symptomatic hips in 107 patients (mean age 15.3 years; SD = 2.0 (range 8–18), 66% female) (Table 1), 44 hips had cam morphology only, 16 had hip dysplasia only, 20 hips had both hip dysplasia and cam morphology present, and 38 hips were normal without cam morphology or hip dysplasia. 81 hips had surgery after their MRI.

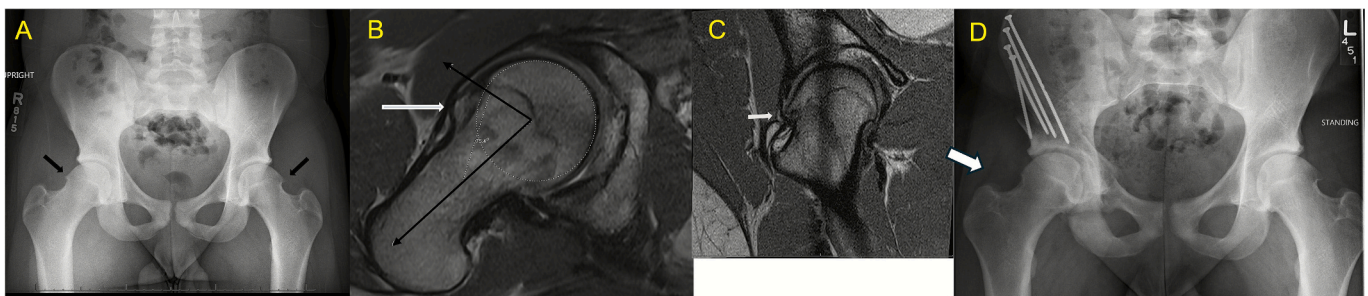


Fig. 1. 17-year-old boy with bilateral hip dysplasia with epiphyseal cam morphology and hip pain. A) AP radiographs demonstrate shallow acetabular roofs bilaterally with LCEAs measuring 16 degrees with epiphyseal cam morphologies (arrows). B) PD oblique axial and C) radial sequence through the anterosuperior proximal right femur demonstrates epiphyseal anterosuperiorly located cam (arrow) with an alpha angle measurement of 75.4 degrees. D) Post-operative radiograph after PAO and femoro-plasty with improved acetabular coverage and more spherical appearance to the femoral head.

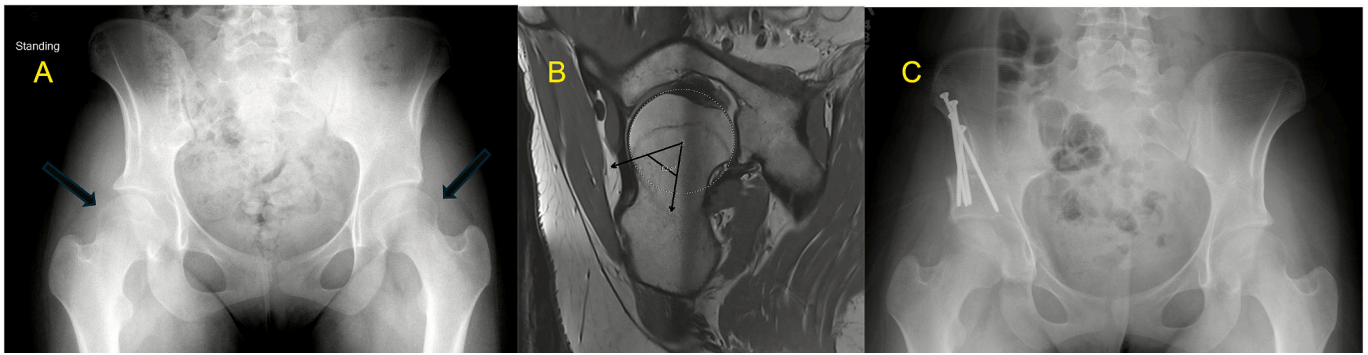


Fig. 2. 17-year-old girl with bilateral hip dysplasia with metaphyseal cam morphology and hip pain. A) AP radiographs demonstrate shallow acetabular roofs bilaterally with LCEAs measuring 17 degrees. B) PD radial sequence through the anterosuperior proximal right femur demonstrates metaphyseal cam morphology with a maximal alpha angle measurement of 62.4 degrees. C) Post-operative radiograph after PAO for treatment of hip dysplasia and femoroplasty.

Table 1
Demographics table.

	Hip dysplasia	No hip dysplasia	All
N	36	82	118
Age at time of imaging (mean + STD)	15.08 ± 2.371	15.44 ± 1.840	15.33 ± 2.013
Range of ages (years old)	8–18	9–18	8–18
Gender			
Female N (%)	24 (30.8%)	54 (69.2%)	78
Male N (%)	12 (30%)	28 (70%)	40

3.1. Cam morphology

64 hips had cam morphology. Of these, 26 were located at the epiphysis (Figs. 1, 3) and 38 located at the metaphysis (Figs. 2, 4) (Table 2). For both epiphyseal and metaphyseal cam morphologies, the most common location was anterosuperior (67.2%) and the second most common location was posterior superior (9.4%). In patients with cam morphology (n = 64), 31 (48.4%) underwent osteochondroplasty to resect the cam morphology. Rates of osteochondroplasty were not statistically significant different between epiphyseal (Figs. 1, 3) (11/26; 68.8%) and metaphyseal (Figs. 2, 4) (20/38; 71.4%) cam morphology cohorts (P = 1.000).

3.2. Hip dysplasia

36 hips in our population had hip dysplasia. The mean LCEA in our hip dysplasia population was 8.6° (SD = 12.23; range: (-45°) - 17°, Median 13.2°). Cam morphology was present in 55.6% (N = 20/36).

There were 82 hips without dysplasia (mean 28.7° (SD = 6.5; range: 18°–44°) and 53.7% of these hips had cam morphology. There was no difference in location of cam morphology in patients with (Figs. 1, 2) or without dysplasia (Figs. 3, 4) (p = 0.612) (Table 2). Of the 36 dysplastic hips, 26 (72.2%) were operatively treated, including 23 (88.5%) which underwent periacetabular osteotomy. For the hips that had hip dysplasia, cam morphology, and had surgery (N = 16), 62.5% (10/16) underwent periacetabular osteotomy with no resection of cam morphology (Fig. 2), 12.5% (2/16) had only osteochondroplasty resection of their cam morphology with no periacetabular osteotomy, and 18.75% (3/16) had both procedures performed (Fig. 1). Patients with underlying hip dysplasia had lower odds ratio of having their cam morphology (OR 0.035, 95% CI 0.006–0.208) treated with osteochondroplasty compared with patients without underlying hip dysplasia.

4. Discussion

FAI and hip dysplasia are two major etiologies of hip pain in pediatric populations. There is ample literature describing each of these entities separately.^{13–16} However, there is a scarcity of literature describing the relationship between the two. We found that cam morphologies are present at similar rates in hips with (55.6%) and without (53.7%) hip dysplasia. Additionally, the location (anterosuperior femoral head/neck junction), and the frequency of epiphyseal based cam morphologies are similar in hips with and without co-existing hip dysplasia. Hip dysplasia and cam morphology have complex pathophysiologic mechanisms, but are probably independent variables related to hip development,^{14–17} since cam morphology occur with the same frequency in hips with or without dysplasia. The presence of co-existing hip dysplasia did not appear to affect the location of cam morphology.

Cam morphology was most commonly identified along the anterior-

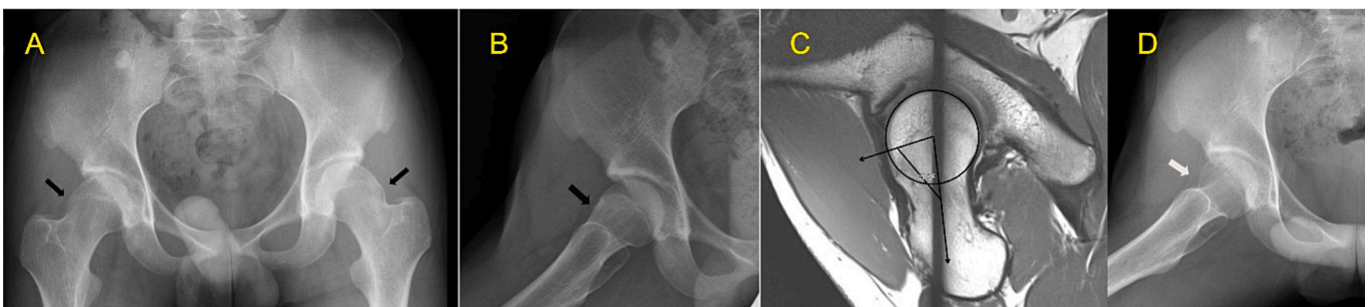


Fig. 3. 16-year-old boy with bilateral epiphyseal cam morphology without hip dysplasia. A) AP and B) right frogleg lateral radiographs demonstrate bilateral cam morphology centered along the epiphyses (black arrows). C) PD radial sequence of the right hip demonstrates anterosuperior cam morphology centered along the juxtaphyseal epiphysis with an alpha angle measurement of 78.9 degrees. D) Frogleg lateral of the right hip demonstrates improved femoral head/neck offset (white arrow) after femoroplasty.

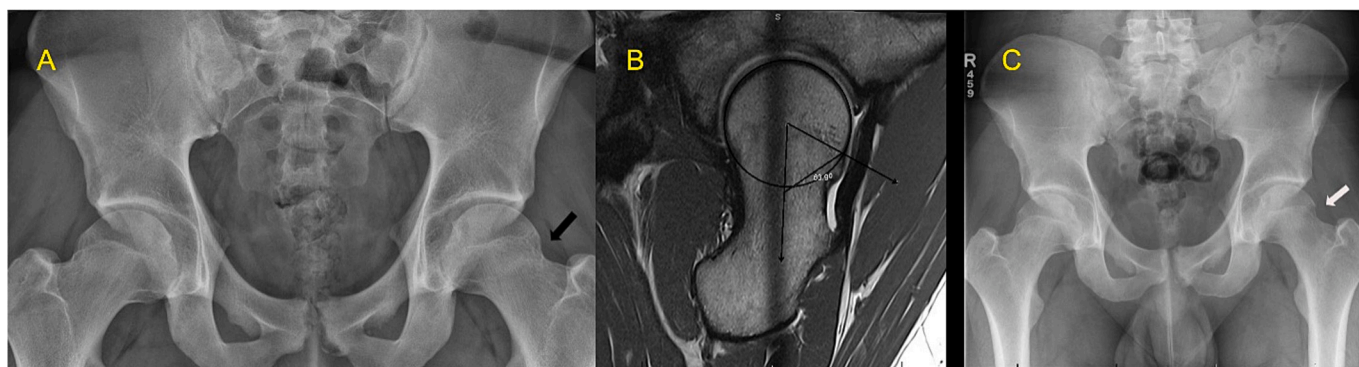


Fig. 4. 17-year-old boy with symptomatic left sided metaphyseal cam morphology without hip dysplasia. A) AP radiographs demonstrate cam morphology (black arrow) along the left femoral neck. B) PD radial sequence of the left hip demonstrates anterosuperior metaphyseal cam morphology with an alpha angle of 63.9 degrees. C) post-operative radiograph after left hip femoroplasty with improved femoral head-neck offset (white arrow).

Table 2
Imaging findings based on MRI hip dysplasia/cam morphology.

	Hip dysplasia (N = 36) N (%)	No hip dysplasia (N = 82) N (%)	P-value
Cam morphology present	20 (55.6%)	44 (53.7%)	0.849
Epiphyseal cam morphology	8 (40%)	18 (41%)	0.945
Metaphyseal cam morphology	12 (60%)	26 (59.1%)	0.945
Cam morphology location			0.747
Anterosuperior	14 (70%)	29 (65.9%)	
All other locations	6 (30%)	15 (34.1%)	
Anterior	2 (10%)	3 (6.8%)	0.612a
Superior	0	5 (11.4%)	
Posterior superior	3 (15%)	4 (9.1%)	
Global/diffuse	1 (5%)	3 (6.8%)	

a = Fisher's exact test.

superior aspect of the femoral-head neck junction in our patients, which aligns with prior literature. One study that evaluated over 3000 cadaveric specimens found patients that 30% had cam morphology with 90.9% located along the anterosuperior and 9.1% located anteroinferior aspect of the proximal femoral neck.¹⁸ Image based studies have shown similar findings, with the prevalence of cam morphology present in 3.5%–66%, and the most common location along the anterosuperior aspect of the femoral neck 19%–91%.^{19–24} In our study, the anterosuperior aspect of the femoral head-neck junction was also the most common location of cam morphology whether there was (70%) or was not (65.9%) underlying hip dysplasia present.

In the setting of co-existing hip dysplasia and cam morphology, the existing cross-sectional imaged based literature in adult patients note the prevalence of cam morphology ranged from 29%–72% and the most common location was along the anterosuperior region ranging from 42%–60%.^{25–27} These prior studies in adult patients with co-existing hip dysplasia are similar to studies in non-dysplastic hips in regard to prevalence of cam morphology and their anterosuperior location.^{18,19,22,24} Our study findings in pediatric patients complement the existing literature regarding frequency of co-existing cam morphologies and their location in the setting of hip dysplasia.

It is well established that the formation of cam morphology is seen mainly in adolescent athletes practicing high-impact sports, and the formation is potentially due to a response of the growth plate under increased loads.²⁸ Hosseinzadeh et al. found that patients with cam-type FAI had larger peripheral cupping, a smaller epiphyseal tubercle and larger metaphyseal fossa as compared with non-athletes. These structures have been shown to be major hip stabilizers, but their presence

may be part of the pathophysiology for cam-type FAI development.²⁸ Dysplasia potentially can change the morphology of cam-type FAI by causing biomechanical instability and could potentially influence the formation of cam morphology (Fig. 5). However, our results show that the presence or absence of underlying hip dysplasia does not appear to change the prevalence or location of cam morphology, including its epiphyseal or metaphyseal location. Knowing the epiphyseal or metaphyseal location of the cam-type morphology is important for pre-surgical planning when femoroplasty is considered since epiphyseal cam morphologies would probably require resecting a greater proportion of articular cartilage compared with a metaphyseal cam deformity. In cases of epiphyseal cam morphologies, the cam morphology may even reside directly beneath the labrum. It is possible to perform an osteochondroplasty in the epiphysis, proximal to the physeal scar with an aim to maintain sphericity of the femoral head and maintain the suction seal of the hip joint while attempting to avoid overresection that could potentially lead to microinstability.^{29,30}

Over half of our patients with hip dysplasia also had a cam morphology. These findings are similar to those of Domb et al. who reported that 65% of their adult population hips with dysplasia had co-existing cam morphology.³¹ To our knowledge, this study is the first to report such a relationship in the pediatric population. This has significant implications on diagnosis and treatment in younger patients. The physician treating a patient with hip dysplasia should be aware of the potential co-existence with cam morphology. Surgical treatment for dysplasia and FAI is distinct. Dysplasia is treated with periacetabular osteotomy and does not require intervention at the head-neck junction where a cam morphology would exist. Similarly, FAI is typically treated arthroscopically at the head-neck junction without addressing the acetabular orientation. Although these procedures are often done in isolation of each other, they may be combined when required based on imaging and intra-operative examination. If the pre-operative decision is made to only treat the dysplasia with a PAO, then, based on our results, intra-operatively the surgeon should reconsider assessing the cam morphology after the PAO is complete to be certain there is adequate hip range of motion. If there is a co-existing labral tear present, repair of the labrum is made at the time of surgery. After correcting the dysplasia, even a small cam morphology may lead to insufficient flexion and/or internal rotation. If motion is insufficient, then the cam morphology may need to be addressed as well.

The limitations of our study include its retrospective design. The diagnostic categorization of findings, including hip dysplasia and cam morphology, was based on retrospective consensus review. In addition, our findings are biased by the nature of referrals since our data reflects patients referred to a pediatric tertiary care subspecialty hip preservation clinic. Another limitation is MRI protocol can vary at different institutions countrywide, and as well as just city-wide. The limitations of

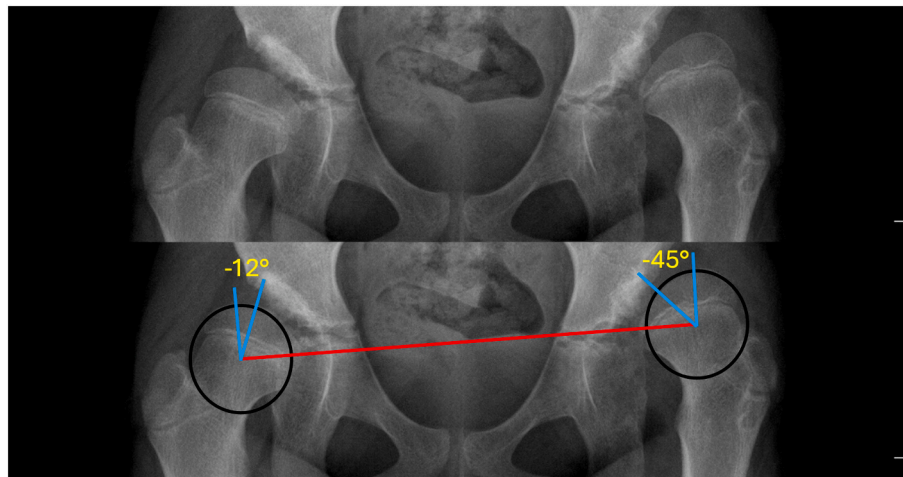


Fig. 5. 8-year-old girl with bilateral hip dysplasia (LCEA: right: -12° LCEA, left: -45° LCEA) with aspherical capital femoral epiphyses with resultant epiphyseal sided CAM deformities present bilaterally.

radial imaging are that there is a lower sensitivity of diagnosing posterior and inferior cam morphology.³² Our results and conclusions may have limited applicability to the general population of pediatric and adult hip pain patients.

5. Conclusion

Pediatric patients with hip dysplasia have a similar prevalence of cam morphology compared with non-dysplastic hips. Cam morphologies most commonly occur anterosuperiorly, whether there is or is not underlying hip dysplasia. It is important to recognize that a high proportion of pediatric hip dysplasia patients may have co-existing cam morphology. Femoral head morphology should be routinely evaluated, and the presence of cam morphology should be detailed when cross-sectional imaging is requested during the pre-operative work-up in pediatric patients with hip dysplasia. Pediatric radiologists and orthopedic surgeons should be aware of cam morphology since they may be a contributing source of pain in pediatric patients with hip dysplasia and their presence may affect the range of motion after a PAO.

CRedit authorship contribution statement

Stuart D. Ferrell: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Samuel X. Ramirez:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Scott B. Rosenfeld:** Writing – review & editing, Methodology, Conceptualization. **Pritish X. Bawa:** Writing – review & editing, Methodology, Investigation. **Andrew C. Sher:** Writing – review & editing, Methodology, Formal analysis. **J. Herman Kan:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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