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Article

Role of Magnetic Resonance Imaging in assessment of osseous and cartilaginous coverage in developmental dysplasia of the hip

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Abstract

Background: Developmental dysplasia of the hip (DDH) can be diagnosed on X-ray by increased acetabular index, which is an indicator of the osseous acetabular coverage. Magnetic Resonance Imaging (MRI) has the advantage of visualization of the cartilaginous and soft tissue structures of the hip. This study aims to assess the role of MRI in assessment of the osseous and cartilaginous coverage of in dysplastic hips and to emphasize the principle of cartilaginous dysplasia of the hip. *Methods*: Consecutive series of 30 patients with DDH (40 dysplastic hips) were examined with radiographs and MRI. Radiographs with antero-posterior (AP) projection were used to measure the radiographic acetabular index (RAI). MRI was used to assess the osseous and the cartilaginous acetabular indices (OAI and CAI) at the coronal proton-density fat-suppressed sequence (PD-FS) *Results*: Significant correlation was found between the radiographic and osseous acetabular indices as well as between the osseous and cartilaginous acetabular indices. No significant difference was found between the radiographic and osseous cartilaginous indices. The osseous acetabular index was significantly larger than the cartilaginous acetabular index. *Conclusion*: Cartilaginous acetabulum is an important parameter that should be actively assessed in dysplastic hips. MRI is a valuable imaging modality that can efficiently assess both the bony and cartilaginous coverage of the dysplastic hips, a major advantage over X-ray.

Keywords: Developmental dysplasia of the hip (DDH), Magnetic resonance imaging (MRI), acetabular index, acetabular cartilage

Background

Developmental dysplasia of the hip (DDH) is a common pediatric disorder. It includes a wide range of abnormalities, including acetabular dysplasia, hip subluxation and dislocation as well as associated soft tissue obstacles to reduction. (1)

DDH is not uncommon, with incidence ranging between 1.5 to 2.5 per 1000 live births. DDH is a serious condition, with untreated DDH can lead to pain, diminished function and premature osteoarthritis due to altered joint biomechanics. (2, 3)

After the age of six months, the diagnosis of DDH is made by X-ray in neutral AP projection using the well-known acetabular index (AI), which is the angle formed by the intersection of Hilgenreiner line, line passing through the tri-radiate cartilage, and line passing from the lateral edge of the tri-radiate cartilage through the supero-lateral corner of the bony acetabulum. AI changes with age, averaging 27.5 degrees in newborns and slightly decreases with age. In routine clinical practice, normal acetabular index is considered to be about 25 degrees and is increased in cases of DDH. (4, 5)

However, there are drawbacks of using the AI measured on X-rays. First, its accuracy is questionable, possibly due to problems with patients positioning or irregular ossification. This may lead to a 6 to 12 degrees of measurement error. Second, X-ray does not visualize the cartilaginous portions of the acetabulum.(6, 7)

Magnetic resonance imaging (MRI) is a non-invasive tool that can be used to assess the bony and cartilaginous components of the acetabulum, soft tissue obstacles to reduction as well as the efficacy of reduction post-operatively. (8, 9)

This study aimed at demonstrating the role of MRI in assessment of the osseous and cartilaginous coverage of the acetabulum in dysplastic hips, by comparing the radiographic acetabular index measured on X-ray (RAI) to the MRI-based osseous acetabular index (OAI) as well as the OAI with the cartilaginous acetabular index (CAI).

Methods

Patient population

Between July 2019 and December 2020, consecutive series of patients attending the clinic of the pediatric orthopedics and deformity unit at our institution was chosen. All patients were over 6 months in age and diagnosed with DDH and planned for either closed reduction or triple attack operation. Informed consent was taken from the parents of all children. The study was approved by the local Ethical Committee at our institution.

We excluded infants less than 6 months of age, where ultrasound was the gold standard for imaging. We also excluded those infants with cerebral palsy and cases of post-traumatic or post-septic dislocation as dislocation was not due to deficient acetabular coverage.

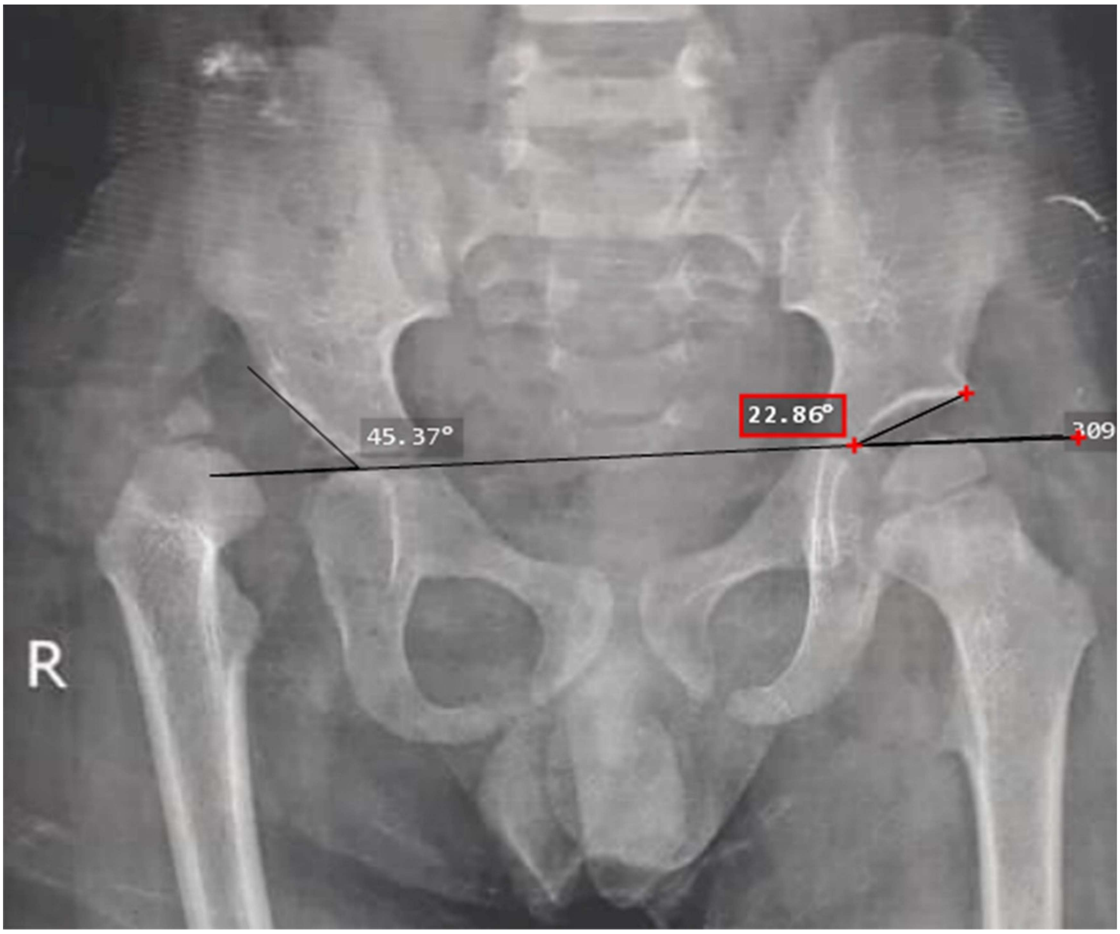
The study included 30 patients, 20 of them had unilateral DDH and the other 10 patients had bilateral DDH. A total of 40 dysplastic hips were examined.

Examination method for X-ray

A general electric (GE) X-ray machine was used to obtain plain X-rays in AP projection in neutral position of the pelvis.

The radiographic acetabular index (RAI) is the angle formed by the intersection of Hilgenreiner line, line passing through the tri-radiate cartilage, and line passing from the lateral edge of the tri-radiate cartilage through the supero-lateral corner of the bony acetabulum. (**Figure 1**).

Figure (1): 2 year 6 month male child presenting with limping and shortening of the right lower limb, due to right hip DDH. X-ray (AP view) of both hip joints showing right hip with increased radiographic acetabular index (RAI), reaching 45.37°. Left hip shows mature osseous acetabulum with normal RAI reaching 22.86°.



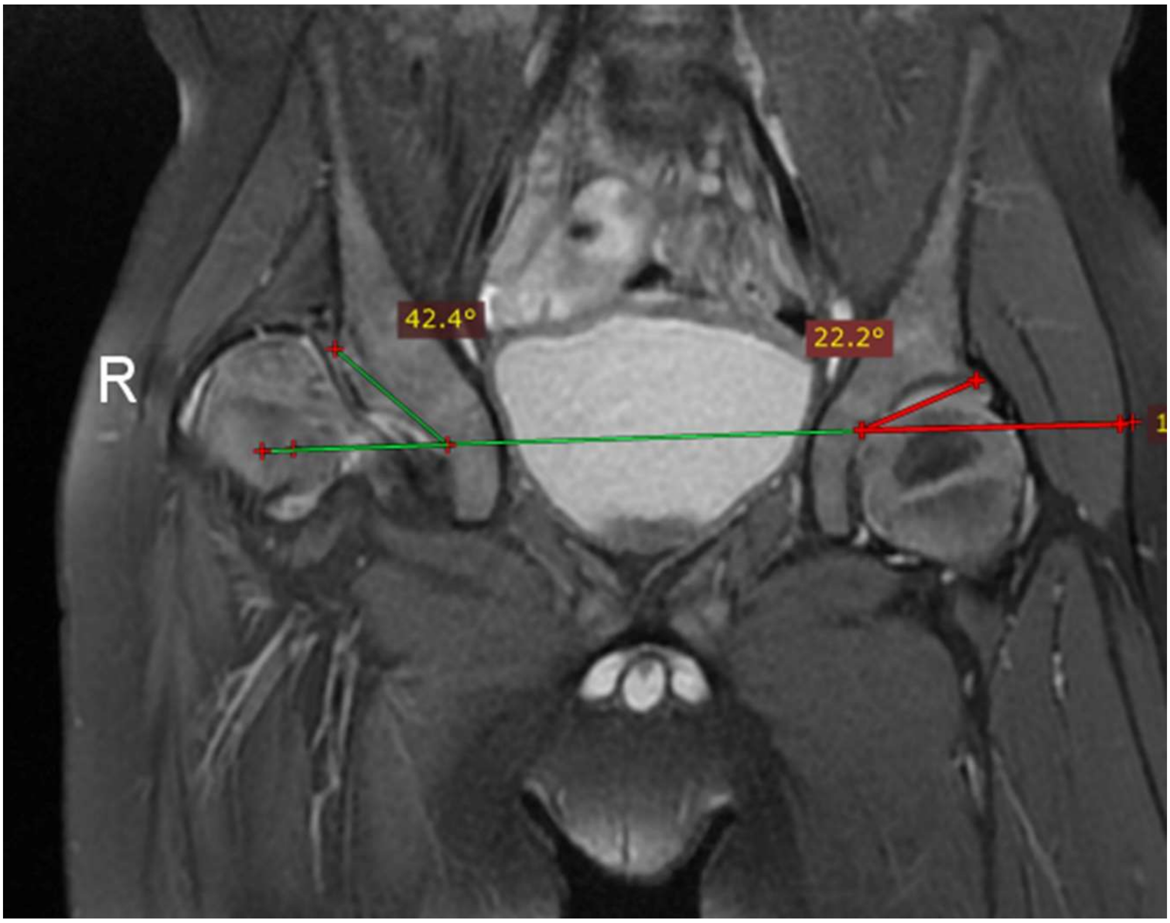
Examination method for MRI

A super-conducting 1.5 T closed MRI scan (Model GE Explorer) by General Electric (GE, USA) was used. The examination was done under sedation by an anesthesia specialist. The patients lied supine with legs in neutral position. A body coil was used placed anterior to the pelvis. Scan range was from the upper parts of the iliac wings till the upper femur.

Fast SE coronal PD pulse sequence was used with the following scanning parameters: TR was 3928 msec, TE was 40 msec, FOV was 220x180mm, matrix size was 320x224 mm, ETL was 16, slice thickness was 3 mm, slice gap was 0.3 mm, and NEX was 4, scan time was 2 minutes 29 seconds. The total scan duration was 2 minutes 47 second, including an 18-seond localizer.

The section chosen for measurements was the mid-coronal cut of the acetabulum which represented its deepest portions. The OAI and CAI were measured in the coronal PD-FS sequence. The osseous acetabular index (OAI) was measured in a similar way to the X-ray. (**Figure 2**)

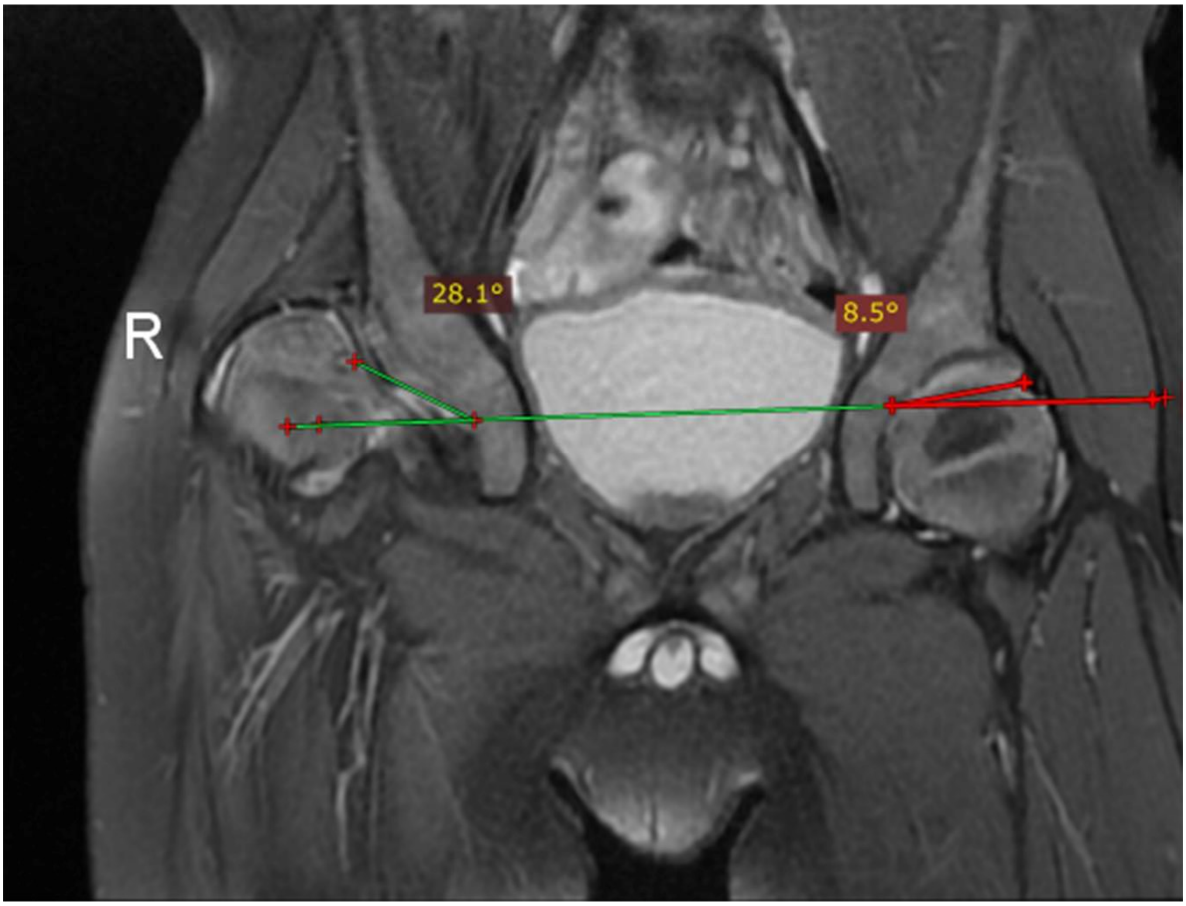
Figure (2): 2 year 6 month male child presenting with limping and shortening of the right lower limb, due to right hip DDH. Coronal PD-FS MRI image of both hip joints, at the mid-level of the acetbulum, showing right hip with osseous acetabular dysplasia and increased osseous acetabular index (OAI), reaching 42.4°. Left hip shows mature osseous acetabulum with normal OAI reaching 22.2°. The OAI measurements are close to those of the RAI.



The cartilaginous acetabular index (CAI) is considered as the angle formed by the intersection of two lines, the Hilgenreiner line, and a line passing from the lateral edge of the tri-radiate cartilage, through the chondro-labral junction. (**Figure 3**)

Interpretation of the radiographs and MRI as well as performing measurements were done by two musculoskeletal radiology consultants, with more than 5 and 10 years of experience in musculoskeletal imaging.

Figure (3): 2 year 6 month male child presenting with limping and shortening of the right lower limb, due to right hip DDH. Coronal PD-FS MRI image of both hip joints, at the mid-level of the acetbulum, showing right hip with cartilaginous acetabular dysplasia and increased cartilaginous acetabular index (CAI), reaching 28.1°. Left hip shows mature cartilaginous acetabulum with normal CAI reaching 8.5°. The CAI normally should be less than 12°.



Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution. The Fisher's exact test

was used to assess the statistical significance. Significance of the results was judged at the 5% level.
The correlation between the RAI and the OAI as well as between the OAI and CAI were assessed. The RAI was compared to the OAI. The OAI was compared with the CAI.
The inter-reader agreement of measurements for RAI, OAI and CAI was done by intra-class coefficient (ICC) using the Pearson correlation test. ICC was set as poor (<0.4), moderate (≥0.4-0.59), strong (≥0.6-0.79) or excellent (≥0.8).

Results

Our cases showed female dominance with 24 girls (80 %) and 6 boys (20%). Mean age at the time of the study was 2.29 ± 1.32 years (range 6 months- 5 years). About 33.3 % of the patients were bilateral (10/30), 40 % of them were right sided (12/30) and 26.7% were left sided (8/20).
History was taken from parents of all patients. Several risk factors for DDH were noted, including history of oligohydramnios, breech presentation, family history of consanguinity and preterm babies. Two cases were associated with talipes equino-varus. (**Table 1**)
The mean radiographic acetabular index (RAI) was 40.86 ± 5.41° in the cases group). The mean osseous acetabular index (OAI) measured by MRI was 41.36 ± 6.07 °.
Comparison between RAI and OAI as well as OAI and CAI was made (**Table 2**). Correlation of RAI with OAI and between OAI and CAI was also assessed.

Table (1): Distribution of the studied cases according to risk factors (n=30)

Risk factors	No.	%
Oligohydramnios	9	30
Breech	7	23.3
Consanguinity	6	20.0
Preterm	4	13.3
Association with TEV	2	6.7

TEV: Talipes Equinovarus

Table (2): Comparison between different parameters (measured in degrees)

	Patients (n=40)	
	Mean ± SD.	**P**
RAI	40.86 ± 5.41	0.409
OAI	41.36 ± 6.07	
OAI	41.36 ± 6.07	<0.001*
CAI	25.08 ± 5.63	

RAI: radiographic acetabular index. OAI: osseous acetabular index. CAI: cartilaginous acetabular index

Significant correlation was found between the RAI and OAI in with Pearson correlation coefficient of 0.792 and P value <0.001 **(Figure 4**). There was no statistically significant difference between the RAI and OAI (P values = 0.409).

The CAI was, by definition, less than the OAI. The mean CAI was 25.08 ± 5.63°. Statistically significant correlation was found between the OAI and CAI, with Pearson correlation coefficient of 0.780 and P value <0.001 (**Figure 5**). Statistically significant difference was found between the OAI and CAI (P value <0.001).

Regarding RAI, CAI and OAI, the overall inter-reader agreement showed strong correlation with ICC of 0.75.

Figure (4): Scatter plot showing correlation between RAI and OAI. Strong correlation was found with Pearson correlation coefficient of 0.792.

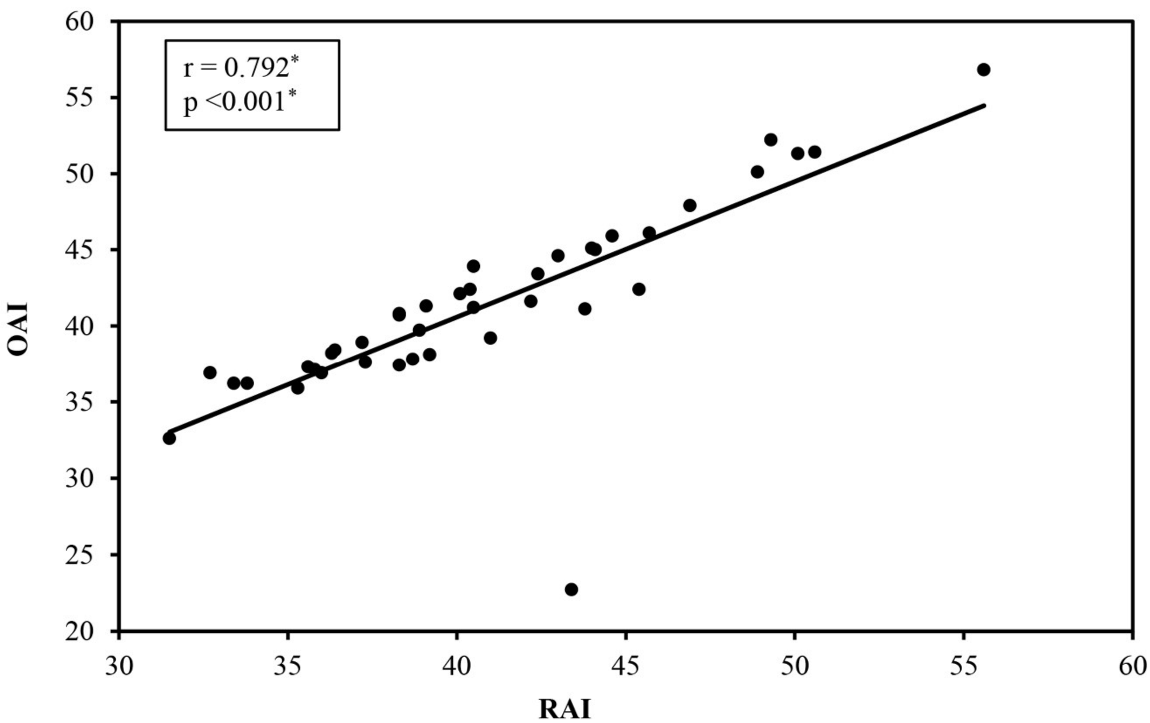
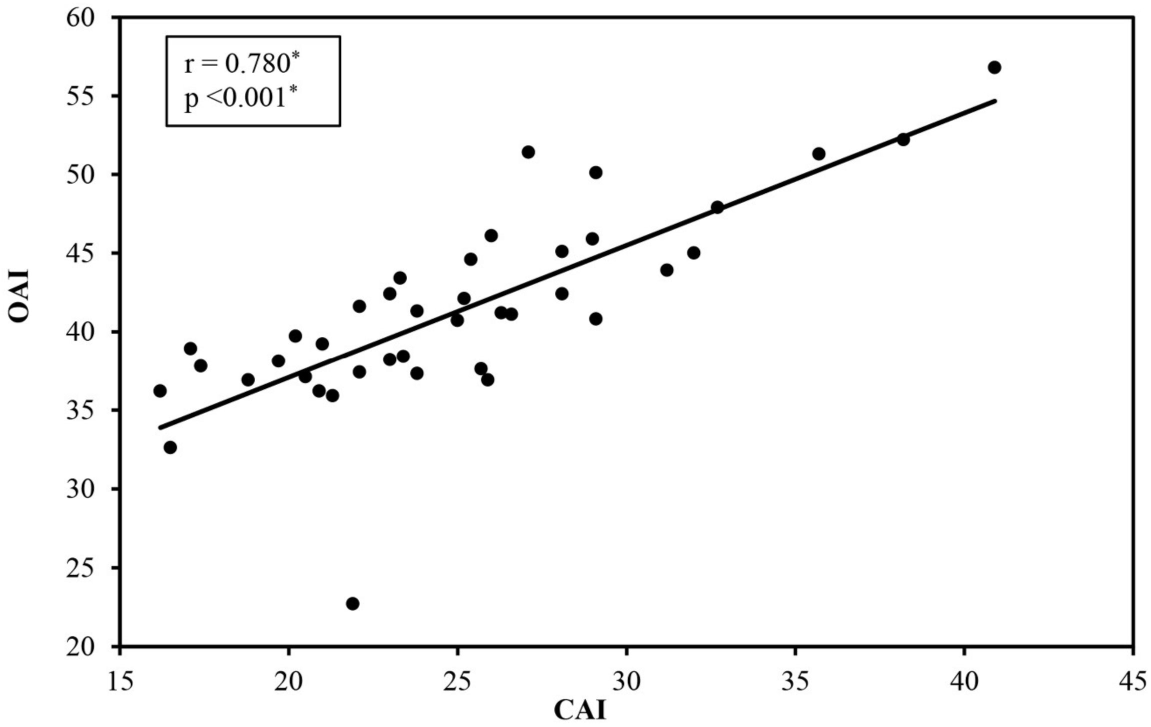


Figure (5): Scatter plot showing correlation between OAI and CAI. Strong correlation was found with Pearson correlation coefficient of 0.780.



Discussion

Our study aimed at demonstrating of the role MRI in assessment of the osseous and cartilaginous coverage of the acetabulum in dysplastic hips. We found statistically significant correlation between the acetabular index measured on X-ray (RAI) and the osseous acetabular index measured by MRI (OAI) with no statistically significant difference. This was similar to the results found by Pirpiris et al. (9) In our opinion, this indicated that MRI has similar efficacy in assessing the bony coverage of the acetabulum. This study has the advantage of higher number of patients (30 patients, 40 hips) compared to 7 patients in the study conducted by Pirpiris et al. These agreed to those of a study conducted by Li et al. (10) On the opposite side, these findings were different from those found by other authors. Huber et al (11) found only fair correlation between RAI and OAI in cases of DDH. A similar study conducted by Duffy et al (12) did not find any correlation. This could be explained by the demographic data. Huber et al had wider range of age (1.2-13 years) with mean age of 7.3 years. Our study was not limited to cases of residual dysplasia. Also Duffy et al measured the acetabular indices at three planes, mid-coronal, anterior and posterior.

This study showed positive linear correlation between the OAI and CAI. This was similar to the results of previous studies. Zhou et al (13) found linear correlation between OAI and CAI in the cases of DDH in different age groups; in infants, young children and children. In a similar fashion, Pirpris et al (9) found positive correlation between OAI and CAI. To the best of the authors' knowledge, the only opposition to this was a study by Zamzam et al, (14) who did not find strong correlation between the acetabular index and the acetabular cartilage angle measured on conventional arthrogrms. This is possibly explained by the different modality as well as the different age groups; Zamzam et al used arthrogram in patients less than 18 months of age. Interesting enough, they, however, found significant correlation in further follow up of some of their patients, who needed pelvic osteotomy at higher age.

The CAI was lower than OAI with statistically significant difference. This is due to the presence of non-ossified cartilage at the lateral acetabular epiphysis, which does not start ossification till the age of 9 years and completes by the age of 15 years. (15, 16) All of our patients were below this age range. Similar findings were obtained by Pirpris et al,(9) possibly due to the difference in range of patient's age (range 3.3-10.5 years, mean age of 7.3 years). This is the only study, to the authors' best knowledge, that assessed the statistical difference between both parameters.

All of our cases showed deficient cartilaginous acetabular coverage, with mean CAI was 25.08 ± 5.63°. This was in accordance with another study conducted by Li et al (10) who defined cartilaginous acetabular dysplasia as being 12 degrees or more.

In our opinion, osseous acetabular coverage is not always a good indicator of the true cartilaginous coverage. Hips with increased RAI and normal CAI, should not be considered as truly dysplastic. They should be better described as delay in enchondral ossification. Li et al(10) showed similar conclusions. Douira-Khomsi et al (17) supported these conclusions and found sufficient cartilaginous coverage in cases diagnosed as dysplastic in X-ray. They followed these patients and found that progressive ossification ensued. Interesting enough, complete correction of the bony coverage was found after follow up of average 2.1 years.

Another importance of measuring the acetabular coverage is predicting the outcome in cases of closed reduction. Zamzam et al (14) concluded a cut off value of 24° for arthrographically determined cartilaginous angle, equivalent to CAI in our study, more than which, pelvic osteotomy was needed. Hips with cartilaginous coverage less than 20 ° had favorable outcome for closed reduction.

These findings draw the attention to the importance of assessment of the CAI, which represents the true cartilaginous coverage of the acetabulum, a major advantage for MRI over X-ray.

Our study is not without limitations. It included the patients as a whole single group, without further age stratification. AI may change with age. The authors recommend further studies with larger number of patients to assess the osseous and cartilaginous development in national infants and children and to establish the percentiles for the radiological parameters of the pediatric hip at different age groups.

Conclusion

The study confirms the importance of MRI as a valuable imaging modality in assessment of not only the osseous, but also the true cartilaginous coverage of the acetabulum in cases of DDH. Cartilage visualization is a major advantage of MRI over radiographs.

Abbreviations

DDH: Developmental dysplasia of the hip; MRI: Magnetic resonance imaging; AI: Acetabular index; RAI: Radiographic acetabular index, OAI: osseous acetabular index; CAI: Cartilaginous acetabular index; ETL: Echo train length, NEX: Number of excitations; FOV: Field of view; SE; fast Spin echo; TE: Echo time; TR: Repetition time; AP: Antero-posterior.

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Ethics approval and consent to participate

This study was approved by the local Ethical Committee at our institution. The parents of all participants provided written consent.

Conflicts of interest

The authors declare that they have no conflicts of interest

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