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Tönnis and the Novel IHDI Radiographic Classification Systems for the Developmental Dysplasia of The Hip (DDH): Evaluation of 406 hips with DDH

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In this study, we aimed to compare the efficiency of Tönnis and the novel International Hip Dysplasia Institute (IHDI) in decision making and in presuming the outcomes in children who had undergone closed reduction and casting. 406 hips of 298 patients who had undergone closed reduction and spica casting were included in this retrospective study. All hips were classified according to Tönnis and IHDI systems. Bucholz-Ogden classification was used for avascular necrosis. The outcomes of patients for each classification system were compared, in terms of the presence of avascular necrosis, redislocations and secondary surgeries at the end of the follow-up period. 318 hips were evaluated as Tönnis grade 2 dysplasia. 24 had avascular necrosis, 9 had redislocations. 79 hips were evaluated as Tönnis grade 3 dysplasia. 18 had AVN, 7 had redislocations. 9 hips were evaluated as Tönnis grade 4 dysplasia 3 had AVN, 4 had redislocations. 203 patients were evaluated as IHDI grade 2 dysplasia. 7 had AVN, 7 had redislocations.185 patients were assessed as IHDI grade 3 dysplasia. 33 had AVN, 11 had redislocations. 18 patients were evaluated as IHDI grade 4 dysplasia. 5 had AVN, 6 had redislocations. Both Tönnis classification and IHDI classification systems are reliable and efficient systems for evaluating the severity and predicting the success of closed reduction and casting for the treatment of DDH. IHDI classification has certain benefits, such as being a practical classification and a better distribution within the groups.

Keywords : Developmental hip dysplasia, Tönnis system, IHDI system, closed reduction.

INTRODUCTION

Developmental dysplasia of the hip (DDH) is one of the most common congenital deformities which has different treatment options depending on the age and severity of the pathology[11]. National screening programs enabled the early diagnosis with hip ultrasonography in first 3-4 months of age. Diagnosis of DDH is done and patients wtih DDH are followed up with the use of pelvic X rays after 6 months of age.

Pelvis X rays have usually been evaluated according to the Tönnis classification for diagnosis and treatment planning. Tönnis classification has been widely used since being proposed in 1978. Still, there is a limited number of studies which evaluate the effectiveness of the classification on presuming clinical outcomes[1,7,9].

Recent articles imply that Tönnis classification had certain limitations which complicate decision making and treatment planning[4,5,7]. First of all, in cases without ossific nuclei classification is done presuming the possible location of the ossific nucleus. Most of the patients who require closed reductions are classified as type 2 without being divided into sub-groups, which comprises prognostic value. The line between the superior acetabular rims is used for classifying type 2,3 and 4. In cases with false acetabuli, it is tough to define the rim. Also, this line is supposed to be vertical to the sagittal body axis. In cases with severe unilateral dislocation, as the superior rim is superior in comparison with the healthy side, the line is oblique to the sagittal axis.

Limitations, mentioned above, of the Tönnis system, resulted in the development of a new classification system by International Hip Dysplasia Institute, which was entitled as IHDI classification[5]. Recent studies revealed that the IHDI classification is comparable or superior to the Tönnis classification in certain aspects[4,5]. One study showed that the IHDI classification had the same prognostic value with the Tönnis classification[7]. Studies regarding the reliability of the novel IHDI classification is limited.

In this study, we aimed to compare the efficiency of both classification systems in decision making and in presuming the outcomes in children who had undergone closed reduction and casting.

MATERIALS AND METHODS

The study was designed as a retrospective study. Ethical approval was obtained from the ethical board of our institution with the number of B.30.2.ATA.0.01.00. 549 cases had closed reduction and spica casting between 2006 and 2017. 65 patients with teratologic and neurologic dislocations, 86 with improper X rays, 46 with less than 12 months of follow-ups, 13 patients who had closed reduction after Pavlik harness treatment with Tönnis grade 1 hips were excluded from the study.

Remaining 406 hips of 298 patients were included in the study. Neutral pelvis anteroposterior (AP) direct X-ray views were used for evaluation and classification.

No patients had traction before closed reduction. Spica casts were applied after closed reduction was assured. Postoperative pelvic AP X-ray views were taken. In cases with suspicious reductions, magnetic resonance imaging was performed after the operation. Patients had been kept in spica casts for two months afterwards; patients had been followed up with abduction braces.

Patients had been followed up at least for the postoperative 12 months. The final evaluation was done according to the Pelvic AP X-ray views at the last follow-up.

No more radiologic evaluation had been done in patients who did not have any residual dysplasia or symptoms regarding the hip joint after 12th month follow up.

Tönnis is classification is based upon the location of the femoral ossific nucleus according to the SMA-line (Line between the superolateral margins of both acetabuli) and Perkin's line (a perpendicular line from the superolateral margin of the acetabulum to the SMA-line). According to the Tönnis classification method: Grade I: femoral ossification center is medial to the P-line. Grade II: the ossification center is

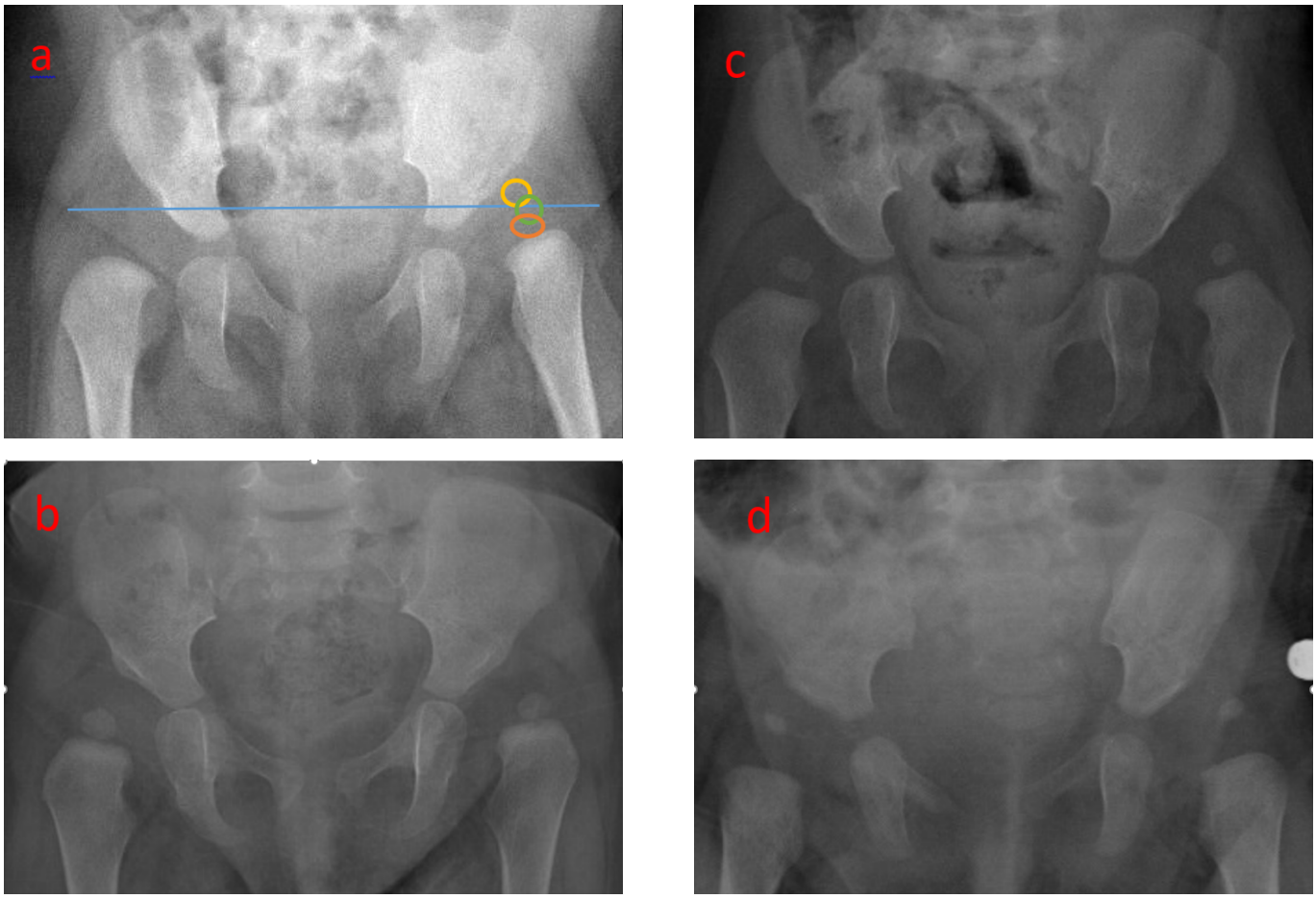

Fig. 1 — (a) 6 month-old girl with bilateral DDH, Both of the ossific nuclei are absent. Tonnis classification is done depending on the presumed place of the ossific nuclei. If we presume the red circle as the ossific nucleus it will be a grade 2 hip, grade 3 for the green and grade 4 for the yellow circle. (b) Tönnis grade 2 hip (c) Tonnis grade 3 hip (d) Tonnis grade 4 hip.

lateral to the P-line but below the SMA-line. Grade III: the ossification center is on or near the SMA-line. Grade IV: the ossification center is above the SMA-line 7 (Figure 6). If there was no ossific nucleus, classification is based upon the presumed place of the ossification center (Figure 1,2a,4).

H point, which is the mid-point of the proximal edge of the femur, is used instead of the ossific nucleus for IHDI classification. Hillgenreiner line is drawn between the upper edge of the triradiate cartilages Perkins line (P line) is drawn from the proximal edge of the acetabulum perpendicular to the H line. Diagonal line (D line) is drawn from the dissection of the H and P lines with 45 degrees of angle laterally. IHDI grade is determined by the position of the H point. In an IHDI grade 1 hip, the H-point is at or medial to the P-line. In grade II, the H-point is lateral to the P-line and at or medial to the D-Line. For grade III, the H-point is lateral to the D-line and at or inferior to the H-line. Finally, in grade IV hips, the H-point is superior to the H-line. (Figure 3b,5)

Preoperative Tönnis grades and IHDI grades, pre- and postoperative acetabular indices (AI), presence of avascular necrosis was evaluated. Bucholz-Ogden classification was used for avascular necrosis evaluation 8. Prognostic values of both of the classification systems were assessed by comparing the outcomes of patients, who had undergone closed reduction and casting, in terms of the presence of avascular necrosis, redislocations and secondary surgeries at the end of the follow-up period.

IBM SPSS 20 was used for statistical analysis. Data are presented as numerals, standard deviation (SD), mean, median, minimum and maximum percentage. The normal distribution of variables was evaluated by the Kolmogorov Smirnov test. Independent samples t-test was used if there was a normal distribution of variables; if not Mann Whitney –U test was used. Statistical significance was set at $p < 0,05$.

RESULTS

Out of 298 patients who had met the inclusion criteria; 170 unilateral cases whereas 118 was bilateral. The mean age was 6,8 months (3-17). There was a femoral head ossific nucleus (ON) in 202 hips and ON was absent in 204 cases. The mean preoperative AI was 36 degrees. Patients consisted of 46 males and 360 females (Table I).

There was grade 1 avascular necrosis in 21 hips, grade 2 in 11, grade 3 in 11 and, grade 4 in 1 hip. 21 patient had redislocations, and 64 patients required secondary surgeries.

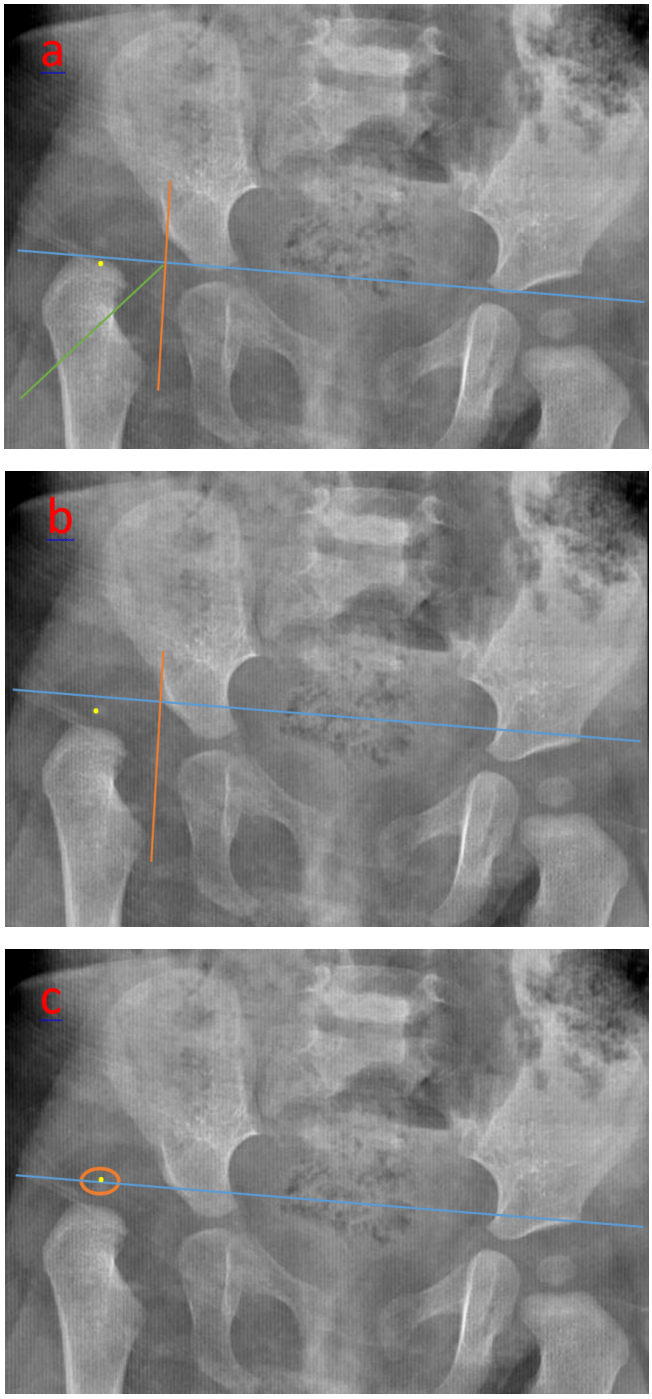

Fig. 2 — (a) 7-month old girl with bilateral DDH superior acetabular rim on the left can be determined easily whereas it is hard to determine the rim on the right. If the blue line is determined to be the SMA line, it is grade 4 dysplasia. If the red line is determined to be the SMA line, it is grade 2 dysplasia according to the Tonnis classification. (b) Evaluation of the same patient according to IHDI system, right hip grade 3, left hip grade 4.

Three hundred eighteen hips were evaluated as Tönnis grade 2 dysplasia. 24 had avascular necrosis, 9 had redislocations, and subsequent surgery was

Table I. — Demographic information of the patients.

	Count	Rate
No of hips	406	100%
Male	46	11,3%
Female	360	88,7%
Unilateral	170	59%
Bilateral	118	41%
Ossific nucleus present	204	49,8%
Ossific nucleus absent	202	50,2%
Right	202	50,2%
Left	204	49,8%
Tönnis		
Grade 2	318	78,3%
Grade 3	79	19,5%
Grade 4	9	2,2%
IHDI		
Grade 2	203	50,0%
Grade 3	185	45,6%
Grade 4	18	4,4%
Avascular necrosis		
AVN absent	361	88,9%
AVN present	45	11,1%
Type 1	22	5,4%
Type 2	11	2,7%
Type 3	11	2,7%
Type 4	1	,2%
Redislocation		
absent	386	95,1%
present	20	4,9%
Secondary Surgeries		
absent	344	84,7%
present	62	15,3%
Mean age of closed reduction (month)	6,87(3-17)	
Mean follow-up (month)	25,18(12-91)	
Mean Preoperative Acetabular index (degree)	38,71(38-54)	
Acetabular index at the last follow-up (degree)	21(12-43)	

necessary for 30 hips. (Table II) 79 hips were evaluated as Tönnis grade 3 dysplasia. 18 had AVN, 7 had redislocation and 25 required subsequent surgeries. 9 hips were evaluated as Tönnis grade 4 dysplasia 3 had AVN, 4 had redislocations, and 4 required subsequent surgeries There was a statistically significant difference between the groups. (p<0,001). Two hundred and three patients were evaluated as IHDI grade 2 dysplasia. 7 had AVN, 7 had

Table II. — Clinical outcomes of the patient according to grades for Tönnis classification.

	Grade 2	Grade 3	Grade 4	p
AVN absent	294 (92,5%)	61 (77,2%)	6 (66,7%)	<0,001
AVN present	24 (7,5%)	18 (22,8)	3 (33,3)	
Redislocation absent	309 (97,2%)	72 (91,1%)	5 (55,6%)	<0,001
Redislocation present	9 (2,8%)	7 (8,9%)	4 (44,4%)	
Secondary Surgeries absent	285 (89,6%)	54 (68,4%)	5 (55,6%)	<0,001
Secondary Surgeries present	33 (10,5%)	25 (31,6%)	4 (44,4%)	

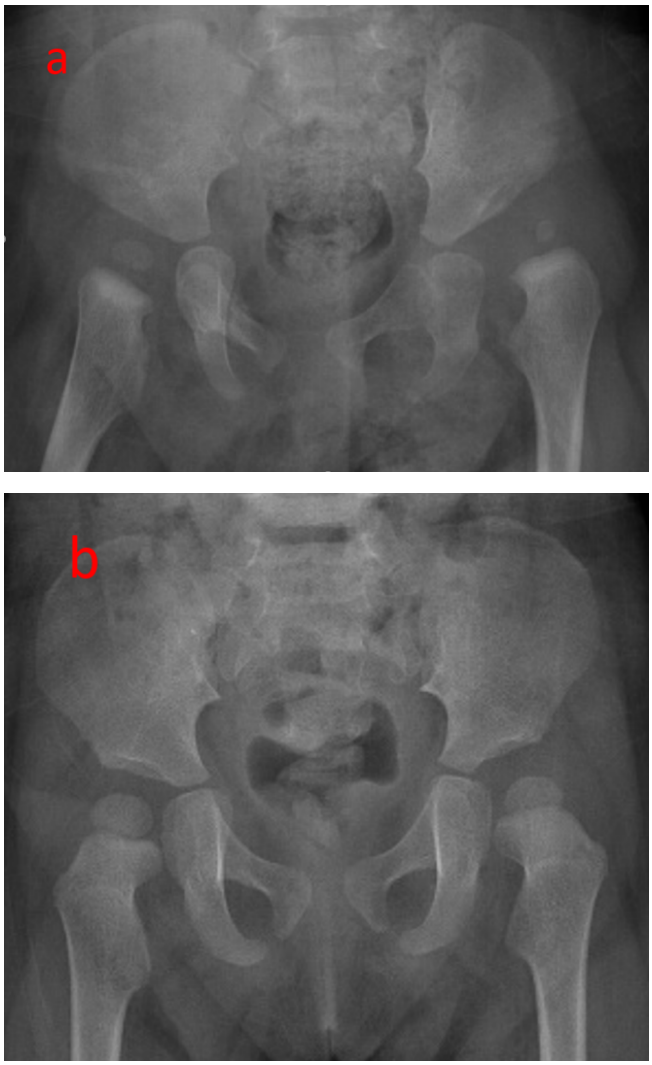

Fig. 3 — (a) 8 month-old girl with DDH, Patient had closed reduction and casting. (b) 12th month follow up pelvis X-ray of the same patient.

redislocations, 7 required subsequent surgeries. 185 patients were assessed as IHDI grade 3 dysplasia.

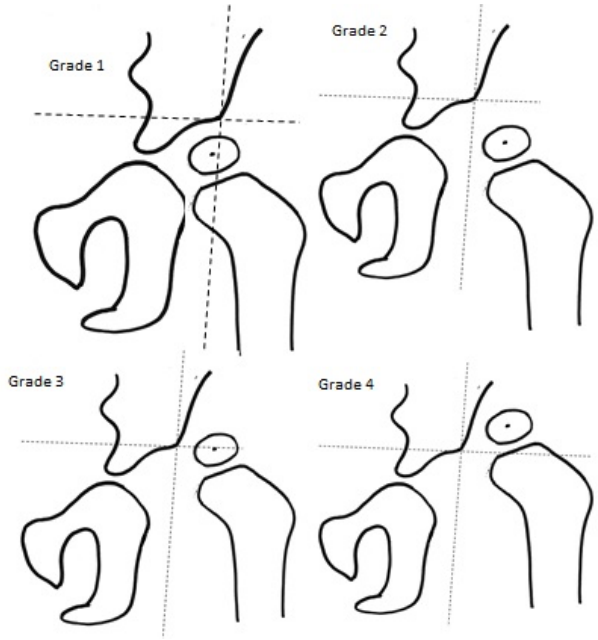

Fig. 4 — Tönnis Classification.

33 had AVN, 11 had redislocations, 47 required subsequent surgeries. 18 patients were evaluated as IHDI grade 4 dysplasia. 5 had AVN, 6 had redislocations, 8 required subsequent operations. There was a statistically significant difference between the groups (p<0,001) (Table III).

Both of the classification systems had satisfactory prognostic value. However, the IHDI system had a better distribution of the subjects within the groups, whereas most of the subjects (73) were classified as grade 2 dysplasia according to Tönnis classification (Table IV).

DISCUSSION

Evaluating the results of our study; increasing grades in both the Tönnis and IHDI groups increased the rate of AVN, redislocations, and secondary surgical procedures (Table II, III). Still, IHDI classification had certain advantages over Tönnis system. First is the absence of the need for a femoral head ossific nucleus for grading the severity of the DDH. As more and more patients are diagnosed before the six months of age number of patients who are followed up without ossific nuclei are increasing, complicating the grading of the pathology. The reliable use of the H point in IHDI system is a significant advantage. The second issue is the H line for IHDI and line between the superior acetabular rims for Tönnis classification. Identifying the superior acetabular rims can be challenging in severe cases, which also can complicate grading for Tönnis classification. This issue can be a somewhat disadvantage for IHDI classification too, as both of the systems use P line, which is the perpendicular line drawn from the superior acetabular rim. Also, most of the patients with DDH are classified as Tönnis grade 2, which result in uneven distribution within the groups.

The primary purpose of the treatment of DDH is to obtain a concentric reduction to prevent possible complications. Recent national early screening programs provided early diagnosis and treatment of the disease, which made closed reduction and spica casting an essential part of the treatment algorithm. Numerous studies have been done to reduce the rates of AVN, redislocations, secondary surgeries. Most of these studies evaluate the effect of the presence of ossific nuclei, acetabular indices of the patients, and

Table III. — Clinical outcomes of the patient according to grades for IHDI classification.

	Grade 2	Grade 3	Grade 4	p
AVN absent	196(96,6%)	152(82,2%)	13(72,2%)	<0,001
AVN present	7(3,4%)	33(17,8%)	5(27,8)	
Redislocation absent	200(98,5%)	174(94,1%)	12(66,7%)	<0,001
Redislocation present	3(1,5%)	11(5,9%)	6(33,3%)	
Secondary Surgeries absent	196(96,6%)	138(74,6%)	10(55,6%)	<0,001
Secondary Surgeries present	7(3,4%)	47(25,4%)	4(44,4%)	
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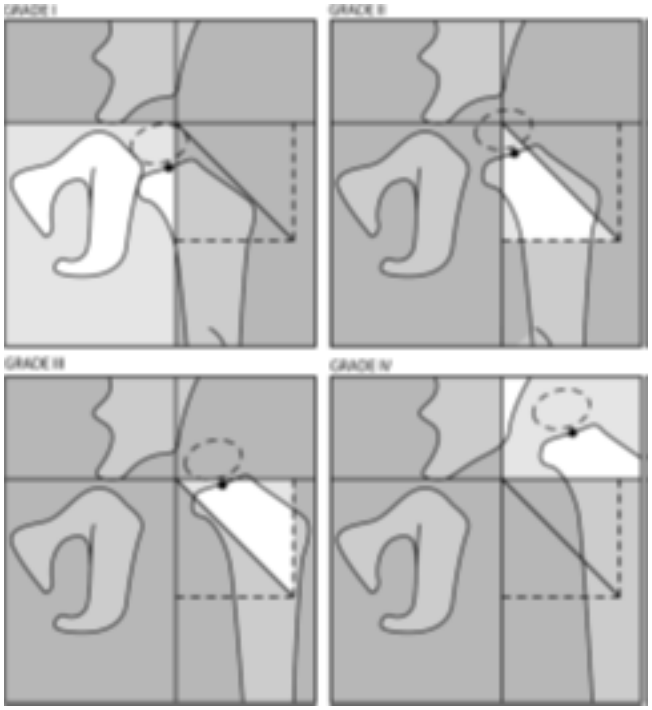

Fig. 5 — IHDI Classification (Narayanan, U., et al., Reliability of a New Radiographic Classification for Developmental Dysplasia of the Hip. J Pediatr Orthop, 2015. 35(5): p. 478-84).

Table IV. — Relationship between the Tönnis and IHDI classification.

			Tönnis		Total
		Grade 2	Grade 3	Grade 4	
	Grade 2	203	0	0	
IHDI	Grade 3	115	70	0	
	Grade 4	0	9	9	
	Total	318	79	9	406

patients age at the intervention time, and so forth[6,8,10]. There is a limited number of studies which evaluate the prognostic values and effectiveness of the classification systems which have been used for decades.

There are 4 classification systems which evaluate the severity of DDH in the literature. Classifications that had been proposed by Yamamuro et al.[13] and Dyson et al.[3] are not being used today. The third, and most widely used, classification was developed by the Commission for the Study of Hip Dysplasia of the German Society of Orthopedics and Traumatology, which is commonly called the Tönnis Classification[1-4,12]. Fourth and the last one is the IHDI classification system, which was proposed by Narayan et al. in 2014[5].

In Tönnis classification system severity of DDH is evaluated depending on the place of the ossific nucleus according to the SMA line (the line between the superolateral margins of both acetabuli) and the P line (a line perpendicular to the H line from the proximal edge of the acetabuli). When Tönnis proposed this method, USG screening was not being performed routinely, and the patients were most commonly diagnosed at walking age with the complaint of limping. Most of the patients had femoral ossific nuclei at waking age, which facilitated classification. National screening programs with the use of USG enabled early diagnosis of the pathology, especially in the first 6 months, which allowed early treatment with Pavlik harnesses, abduction braces, and closed reduction. Most patients do not have apparent femoral ossific nuclei before the 6 months of age, which complicate radiologic classification.

Despite being used for nearly three decades, there is a limited number of studies which evaluates the effectiveness and prognostic value of the Tönnis classification. Rosen et al.[9] reported every increase in Tönnis grade results in a two-times increase of AVN in their 81 cases series in 1999. A most significant limitation of the study is that patients who had undergone open reduction closed reduction and Pavlik harness treatment are included to the study population and number of patients who had undergone closed reduction is only 32. Bolland et al.[1] reported that Tönnis grade 4 patients had undergone more secondary surgical procedures significantly then Tönnis grade 2 patients in their series, which included patients who had undergone closed or open reductions. Ramo et al.[7] had performed a closed reduction to 235 hips of patients who were between 6 to 36 months of age. They have compared the prognostic value of Tönnis and IHDI classification systems on clinical outcomes, and they have concluded that the IHDI classification system was more facile to use and both of the systems had had satisfactory prognostic values. A most significant limitation of this study is that it included patients who were only older than 6 months of age. One of the essential benefits of IHDI classification is that it does not depend on the femoral ossific nucleus, which is generally absent before the 6 months of age.

In the design of this study, we also aimed to resolve the limitations of the previous studies. Our number of subjects was relatively high, and only patients who had undergone closed reduction were included. Also, the age of the patients was close (3mo-17mo).

The most important limitation of our study is the retrospective design. Prospective, randomized, multicenter studies should be done in the future. Second is that our follow up period is relatively short, and we have not done any radiologic evaluation after 12 months of follow-up in asymptomatic hips without any residual dysplasia. The third is that patients who

had undergone closed reduction was evaluated only with pelvic X ray views after the procedure which may have resulted in inaccurate evaluation in reduction.

CONCLUSION

In conclusion, earlier diagnosis and treatment of DDH resulted in limitations for Tönnis classification due to the lack of anatomic landmarks for pelvic X rays. IHDI classification system proved to be a reliable and efficient system for evaluating the severity and predicting the success of closed reduction and casting for the treatment of DDH. IHDI classification has certain benefits, such as being a practical classification and better distribution within the groups.

Ethics Committee Approval: Ethical approval was obtained from the clinical ethical board of Ataturk University with the number of B.30.2.ATA.0.01.00/. and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study. Patients' parents signed informed consents on the conduction of diagnostic procedures and medical interventions.

Conflict of Interest: All of the authors declared no conflict of interest.

Financial Disclosure: The authors declared that this study had received no financial support.

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