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Research Article

Clinical and radiological outcomes of Salter versus Pemberton osteotomies in the management of developmental dysplasia of the hip: A retrospective comparative study

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ABSTRACT

Objective: The aim of this study was to investigate whether there is a relationship between Salter and Pemberton pelvic osteotomies and avascular necrosis of femoral head in the management of developmental dysplasia of the hip (DDH).

Methods: This retrospective study included 69 hips of 52 patients aged between 12-36 months, diagnosed as DDH who had undergone either Salter or Pemberton pelvic osteotomy with Smith Petersen approach. There were 35 patients in Salter Pelvic Osteotomy and 34 patients in Pemberton Pelvic Osteotomy groups. Before the treatment of DDH, Tönnis classification was used, preoperative and 24th month postoperative Acetabular Index (AI) angles were measured. Kalamchi-MacEwen grades of avascular necrosis were determined in terms of presence of avascular necrosis of the femoral head.

Results: There were no significant differences between two osteotomy groups at the end of mid-term follow up in terms of the radiological parameters and avascular necrosis of femoral head. However it was found that the increased avascular necrosis incidence was significantly associated with Tönnis grade 4 hips.

Conclusion: Salter and Pemberton osteotomies can be both used safely in the treatment of DDH regarding their effect on the femoral head.

Level of Evidence: Level III, Therapeutic Study

Introduction

Developmental Dysplasia of the Hip (DDH) is a frequently seen disease that includes a wide spectrum of abnormalities, which may lead to early hip joint degeneration.[1] Deterioration of the femoral head and acetabular shape and volume is well defined in the literature.[2,3] Treatment modalities include closed reduction, open reduction, open reduction and pelvic osteotomy, open reduction, pelvic osteotomy, and femoral shortening. Treatment is determined by the age of the patient mostly, but despite the treatment, some structural changes of the hip joint and acetabulum may be sustained or appear as the complication of treatment itself.[4] Avascular necrosis, coxa vara, and coxa valga mostly involve structural changes that lead to functional disabilities in adulthood and require secondary surgical interventions. However, Avascular Necrosis (AVN) of the femoral head is one of the complications that is mostly attributed in the literature. Structural changes can be seen regardless of extension of the treatment, even with closed manipulative techniques. However, such structural changes have been managed by various investigators, and various factors have been implicated. Recurrent dislocations and consequent surgeries, medial approach, age, and inadequate splint and brace use were determined to be possible risk factors for AVN.[5,6] Some authors claimed that extensive unelaborated dissection can impose a burden of surrounding soft tissue injury and vascular damage, which may cause anatomical deterioration and subsequent radiographic changes.[7] On the other hand, standard steps of open reduction, such as capsulorrhaphy, fibrous fatty tissue removal, and ligamentum teres excision, have been stated as possible risk factors. Pelvic osteotomies were also discussed under a previous topic. Salter Pelvic Osteotomy (SPO) and Pemberton Pelvic Osteotomy (PPO) are used for reshaping and redirection of the acetabulum, respectively, in patients who have clinically and radiologically detected acetabular dysplasia in similar age groups.[8,9] The relationship between the osteotomy type and structural changes has been evaluated in the literature.

Differences in the execution of osteotomies may yield different consequences. These features require detailed preoperative planning before osteotomy selection. For example, DDH patients who have a wide femoral head are not candidates for acetabuloplasties; rather, Salter osteotomy can be a more appropriate option. However, both acetabuloplasties and SPO have been reported to be effective in terms of acetabular reshaping and redirection to increase the joint

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stability and coverage of the femoral head. Changes in the hip joint capacity or coverage of the femoral head can be related to the alteration of pressure on the femoral head. We thought that PPO may be more related to AVN and other structural changes in the femoral head and hip joint due to its proximity to the acetabulum and that PPO may lead to alteration of the joint capacity. Therefore, in this paper, we aimed to investigate the short-term radiological results of DDH patients who were treated with PPO and SPO.

Materials and Methods

Informed consent and institutional review board approval were obtained (Decision No: 34; 10.10.2014). Data on the children with respect to their radiographic images, demographic information, and health conditions were extracted from our hospital records. This was a retrospective study that included 69 hips of 52 patients who were treated with a diagnosis of DDH between January 2012 and December 2015. Patients who received previous treatment for DDH and presented concomitant lower-extremity pathology or neuromuscular diseases such as myelomeningocele, arthrogryposis, cerebral palsy, and collagen tissue disorder were excluded. Children who underwent femoral shortening were also excluded. All patients who had DDH diagnoses were extracted from the database of the hospital. Inclusion criteria were specified as ages between 12 months and 36 months and patients who had undergone open reduction or pelvic osteotomy (SPO or PPO) by the Smith Petersen approach with at least 24 months of regular follow-up. Patients who had regular follow-up but experienced recurrences after surgery were also elicited. As a result, 35 patients in the SPO and 34 patients in the PPO groups met the inclusion criteria. There were 21 left, 15 right, and 16 bilateral DDH cases. Six patients were male, and 46 patients were female. The mean age was 24.8 ± 5.5 months. The youngest patient was 16 months old, and the oldest patient was 35 months old. In bilateral cases, patients were included if the operation age of the latter was less than 36 months. At our institute, we prefer to have at least 6 months of intermission between operations for bilateral cases and to perform the same osteotomy type on both hips.

Patients were assessed with standardized AP pelvis views radiologically before the intervention and during the follow-up. Supine radiographs were obtained with the pubic symphysis 100 cm away from the X-ray beam source. Four hips were graded as Grade 1, 11 as Grade 2, 19 as Grade 3, and 35 as Grade 4 according to the Tönnis classification.[10] The Acetabular Index (AI) and Wiberg's Center Edge (CE) angle were measured, and persistent avascular necrosis of the femoral head was classified according to the Kalamchi-MacEwen classification at the end of the 24th-month follow-up.[11] Other changes, such as coxa valga or coxa vara without AVN, were also noted.

The surgical approach was standard (percutaneous adductor tenotomy, anterolateral approach, open reduction, and capsulorrhaphy) and performed by the same surgeon. Six weeks of spica cast immobilization were applied following surgery. The positions of the hips were adjusted to the functional position (15° flexion, 15° abduction, and neutral rotation). An addition of 6 weeks of brace use was also prescribed. Case examples are given in Figures 1-3.

The background data included age, sex, side, and preoperative Tönnis classification. The rate of osteonecrosis and background data were compared between the two groups using an independent *T* test for continuous variables and a chi-squared test for categorical values. The analysis was completed with SPSS, version 17.0 (SPSS Inc. Chicago, IL), and a *P* value of <0.05 was regarded as significant.

HIGHLIGHTS

- Avascular necrosis of femoral head is an iatrogenic sequel of the treatment of developmental dysplasia of the hip (DDH).
- The aim of this study was to investigate whether there is a relationship between Salter and Pemberton pelvic osteotomies and avascular necrosis of femoral head in the management of DDH.
- The results showed that both osteotomies can be performed safely without a significant AVN risk. Femoral shortening osteotomies should be considered in forceful reduced hips or if circumferential soft tissues is considered to be more streched than expected.

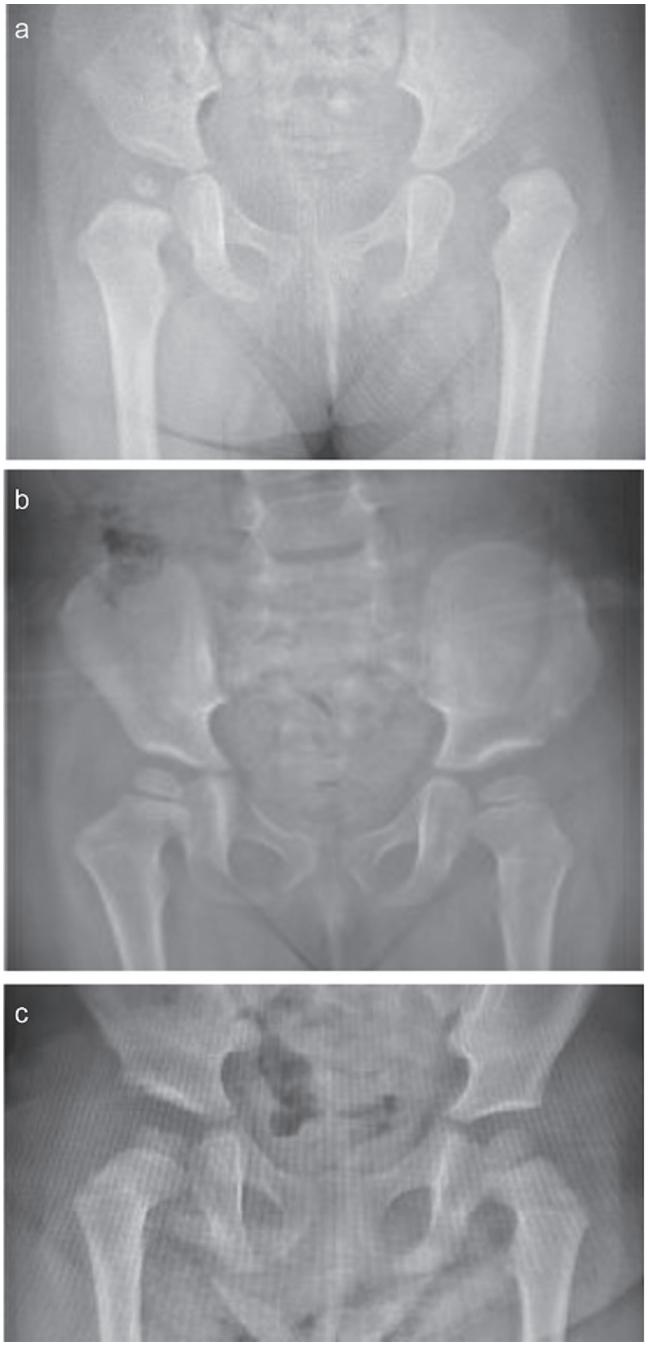


Figure 1. a-c. (a) Female,16 months, left DDH, Tönnis grade 3 hip; (b) SPO, early postoperative radiographic view; (c) Postoperative 24th month, remarkable widening in the left hip.



Figure 2. PPO. Postoperative 24th month, Kalamchi-MacEwen grade 2 avascular necrosis, with superolateral irregularity in the acetabulum.

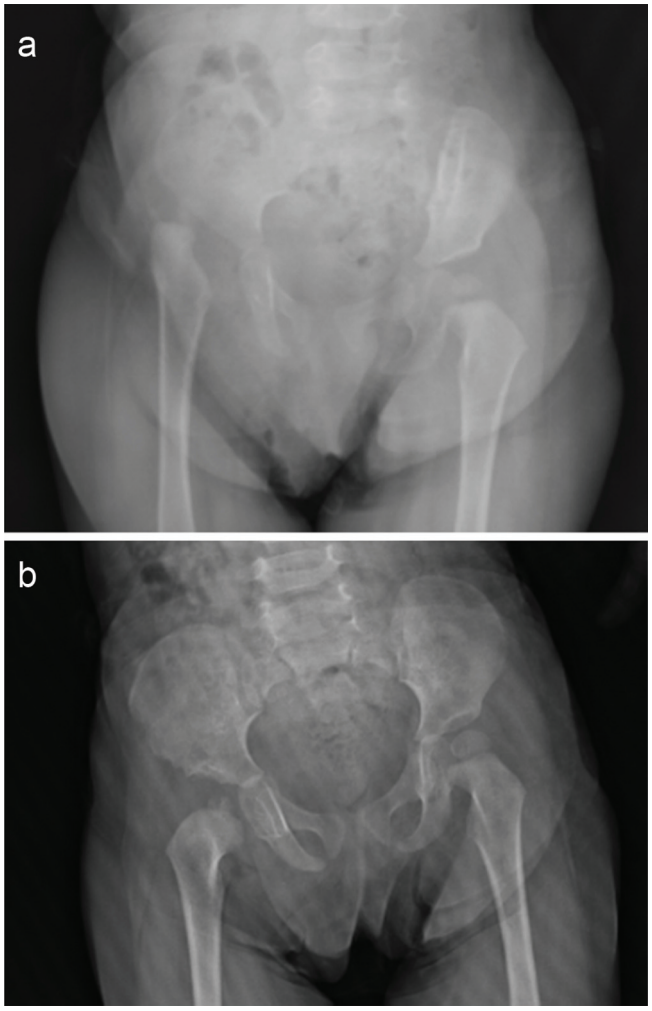


Figure 3. a, b. (a) Female, 19 months age, Tönnis grade 4 DDH; (b) Global physeal injury in the right hip (Grade 4 avascular necrosis according to Kalamchi Mac-Ewen classification).

Results

There was no significant difference in terms of sex, side, Tönnis grade, or age at surgery between the two osteotomy groups. The overall mean AI in the PPO group was 36.2° ± 4.9° preoperatively and 23.4° ± 3.9° at the end of the 24th month. The overall mean AI in the SPO group was 35.6° ± 3.8° preoperatively and 23.1° ± 5.7° at the end of the 24th month (Table 1). The postoperative Wiberg's Center Edge Angle (CEA) was 23.5° ± 10.4° in the PPO group and 20.6° ± 11.7° in the SPO group. The relationship between AVN rates and AI correction, AVN rates and preoperative AI, and AVN rates and preoperative CEA angles were evaluated, and no correlation was found.

The overall avascular necrosis rate was 23.2% (16 of 69 hips). There were eight hips with avascular necrosis in both the PPO and SPO osteotomy groups, without any significant difference (Table 2). The correlation between the Kalamchi-MacEwen grade of the AVN and osteotomy type was also investigated, and no significant difference was found (Table 3). Tönnis grades of patients who had avascular necrosis were also noted. One hip was grade 2, 3 hips were grade 3, and 12 hips were grade 4. There was no correlation between AVN and Tönnis grades in grade 1-3 hips; however, significantly increased rates were detected in grade 4 hips (Table 4).

Discussion

Providing a concentric reduction of the hip joint is the main objective in the treatment of patients with DDH.[11-13] Age, physical examination, presence of concomitant diseases, and radiographic findings are important indicators for determining adequate treatment. Patients over 18 months of age generally require additional pelvic osteotomy for correction of the acetabular index and effective femoral head coverage.[14] Pelvic osteotomies can be made mandatory in cases of patients who are 12-18 months of age and in greater than the 95th percentile, as well as in exceptional conditions such as intractable instability despite open reduction to improve stability and correct acetabular misdirection. Salter and Pemberton's pelvic osteotomies are the most popular pelvic osteotomies and are performed in similar age groups.[15,16]

DDH may cause early-onset proximal femoral deformities such as coxa valga, coxa vara, and femoral head avascular necrosis, or these deformities may also be encountered as sequelae of inadequate treatment, which results in devastating problems in adulthood. Femoral head avascular necrosis is the most common complication after surgery at different levels and may lead to premature hip joint osteoarthritis, the incidence of which is reported to be 6-48% percent after DDH surgery.[17-20] There are many theories on how surgery could lead to AVN and structural changes. Open reduction can cause AVN solely via injury to vessels in the capsule; a technique that mandates capsulotomy or pulvinar and ligamentum teres excision can also lead to structural changes.[19] Medial exposure is considered to create a higher risk for AVN, owing to possible medial circumflex artery damage. In

Table 1. There was no correlation between postoperative AI improvement and AVN

	AVN of the femoral head				
	No		Yes		
	Mean ± SD	Med (Min-Max)	Mean ± SD	Med (Min-Max)	*P*
PREOP AI	36,0 ± 4.4	36.2 (29.0-46.3)	35.6 ± 4.3	35.1 (30.0-45.0)	0.758
POSTOP AI	23.3 ± 5.0	23.0 (10.0-36.1)	23.2 ± 4.8	23.0 (15.0-30.8)	0.975

Table 2. There was no significant difference between osteotomy groups

AVN	Total	PPO	SPO	*P*
No	53 (76.8)	26 (76.5)	27 (77.1)	1.000
Yes	16 (23.2)	8 (23.5)	8 (22.9)	

Table 3. Relationship between osteotomy type and Kalamchi-MacEwen AVN Grade of the hips were separately correlated. There was no relationship between osteotomy type and subgroups of Kalamchi-MacEwen classification

		Osteotomy (n(%))		
	n(%)	Pemberton	Salter	*P*
Kalamchi-MacEwen				
0	53 (76.8)	26 (76.5)	27 (77.1)	
1	5 (7.2)	5 (14.7)	0 (0.0)	0.053
2	3 (4.3)	1 (2.9)	2 (5.7)	
3	4 (5.8)	0 (0.0)	4 (11.4)	
4	4 (5.8)	2 (5.9)	2 (5.7)	
AVN				
NO	53 (76.8)	26 (76.5)	27 (77.1)	1.000
YES	16 (23.2)	8 (23.5)	8 (22.9)	
Tönnis				
1	4 (5.8)	2 (5.9)	2 (5.7)	
2	11 (15.9)	4 (11.8)	7 (20.0)	0.829
3	19 (27.5)	10 (29.4)	9 (25.7)	
4	35 (50.7)	18 (52.9)	17 (48.6)	

Table 4. Preoperative Tönnis Grade and its relationship with AVN. When each group was considered on its own, there are no statistical differences between groups in terms of AVN. However, group 4 included the highest number of AVN cases and statistically higher than the combination of other groups

	Total	AVN		
	(n(%))	No (n(%))	Yes (n(%))	*P*
TONNİS				
1	4 (5.8)	4 (7.5)	0 (0.0)	
2	11 (15.9)	10 (18.9)	1 (6.3)	0.142
3	19 (27.5)	16 (30.2)	3 (18.8)	
4	35 (50.7)	23 (43.4)	12 (75.0)	
TONNİS				
1-3	34 (49.3)	30 (56.6)	4 (25.0)	0.044
4	35 (50.7)	23 (43.4)	12 (75.0)	

our study, all surgeries were performed with the same exposure to minimize the possibility of iatrogenic injury and technical variations to prevent misinterpretations of the findings. AVN may not always be related to vascular disturbance of the femoral head. Pressure on the femoral head may also lead to growth disturbance of the femoral head, which may mimic AVN. This may explain why in some cases, the femoral head could be affected globally or partially.[18] On the other hand, redislocations and repetitive manipulative interventions are considered risk factors for femoral head AVN in DDH patients.[14] In this study, we excluded patients who had a previous history of treatment or intervention for DDH.

The relationship between pelvic osteotomies and AVN has previously been investigated. Regardless of the osteotomy type, some authors have thought that AVN rates are highly related to the extension of the intervention. One study that compared pelvic osteotomy with open reduction and open reduction of the hip alone revealed that patients with an additional pelvic osteotomy had higher AVN rates.[21] However, the authors of other studies have emphasized that pelvic osteotomies do not contribute to an additional risk of AVN. Castaneda et al. reported that there was no significant difference between patients who underwent open reduction and open reduction with pelvic osteotomy. They also concluded that pelvic osteotomy significantly decreased the risk of reoperation due to the redislocation of the hip joint.[22] Since there are controversies regarding pelvic osteotomy and AVN, we randomly selected patients who had only SPO and PPO. We found that the overall AVN rate was 23.2%. Rates were 23.5% in the PPO group and 22.9% in the SPO group. These rates were consistent with AVN rates in the literature. PPO is believed to increase the vulnerability to AVN due to the proximity of the osteotomy line to the acetabulum, leading to a shallower acetabulum. We found no significant difference between the SPO and PPO groups in our study.

Patients older than 18 months who have DDH associated with high AI require pelvic osteotomy.[23] We believed that correction of the AI may increase pressure on the femoral head. Aydin et al. specified that PPO provides a better correction over AI and CEA in the early postoperative period; however, the proximity of PPO to the acetabular edge and damage to the secondary ossification centers of the acetabulum may increase the depth, which could negatively impact development of the acetabulum and femoral head.[20] Aydin et al. reported the results of pericapsular Pemberton pelvic osteotomy performed on patients and determined the incidence of AVN to be 18.6%, which was consistent with similar studies. In the present study, we obtained a mean correction angle of 12.59° ± 5.12°. There was no significant difference between the two osteotomy groups in terms of AI correction. Therefore, both PPO and SPO yielded an effective and similar amount of AI correction. The relationship between AI correction and AVN was also found to be insignificant.

The Tönnis classification system is widely used for planning DDH treatment.[18] In the literature, many papers have investigated the correlation between the preoperative Tönnis grade and AVN rates. Li Yi-Qiang et al. reported that AVN rates after DDH treatment were related to the Tönnis grade of the patient independent of the treatment.[13] Similarly, we found that Tönnis grade 4 patients had significantly higher AVN rates (34.3%). Since we excluded patients with femoral shortening, high AVN rates could be related to the increased pressure over the femoral head after reduction, as the surgeon refrained from femoral shortening. We concluded that excess tension of surrounding soft tissue must be avoided after reduction. Femoral shortening osteotomy should be considered in case of any such concern.

One weakness of this study was the sizes of the groups, which were small with a short-term follow-up; this may have obscured the real incidence of AVN or its potential effects on the femoral head. Therefore, long-term follow-up with wider groups would provide more accurate results in terms of comparison of osteotomies and accurate AVN rates. Unfortunately, patients in our vicinity generally cease follow-up arbitrarily. The same surgeon performed all surgeries, and only patients without any previous treatment or concomitant disease were included; these are the strengths of the study.

The unique aspect of this study is that the patients received no conservative or operative treatment until their first late application to our facility. These patients should have received proper management at a much earlier age but remained neglected, a disadvantage that helped us study the results of two different osteotomies in untreated overlooked subjects.

In conclusion, in terms of AVN of the femoral head, both osteotomies are safe surgical procedures chosen in specific indications for the treatment of DDH. However, cases with higher Tönnis grades should be handled more cautiously during preoperative planning.

Ethics Committee Approval: Ethics Committee approval was received for this study from the Clinical Research Ethics Committee of Çukurova University (Decision No: 34; 10.10.2014).

Informed Consent: Informed consent was obtained from the patients.

Author Contributions: Concept - A.M., Ö.S.B.; Design - M.A.D., C.Ö.; Supervision - Ö. S.B., M.A.D., C.Ö.; Materials - Ö.S.B.; Data Collection and/or Processing - Ö.S.B., C.Ö., M.B.; Analysis and/or Interpretation - A.M., M.T., M.A.D., M.B.; Literature Review - A. M., M.T., M.A.D.; Writing - A.M., M.B.; Critical Review - C.Ö., M.B.

Declaration of Interests: The authors have no conflicts of interest to declare.

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References

1. Cambell's Operative Orthopaedics 12th Edition. Elsevier Mosby, Philedelphia. 2013;1079.
2. Gotoh E, Tsuji M, Matsuno T, Ando M. Acetabular development after reduction in developmental dislocation of the Hip. *Clin Orthop Relat Res*. 2000;378 (378):174-182. 10.1097/00003086-200009000-00027
3. Clohisy JC, Nunley RM, Carlisle JC, Schoenecker PL. Incidence and characteristics of femoral deformities in the dysplastic hip. *Clin Orthop Relat Res*. 2009;467(1):128-134. 10.1007/s11999-008-0481-3
4. Tang H-C, Lee W-C, Kao H-K, Yang W-E, Chang C-H. Surgical outcomes of developmental dysplasia of the hip with or without prior failed closed reduction. *J Pediatr Orthop*. 2015;35(7):703-707. 10.1097/BPO.0000000000000374
5. Bowen JR. *Kotzias-Neto A Developmental Dysplasia of the Hip*. Brooklandville, MD: Data Trace Publishing Co.; 2006.
6. Pollet V, Van Dijk L, Reijman M, Castelein RMC, Sakkers RJB. Long-term outcomes following the medial approach for open reduction of the hip in children with developmental dysplasia. *Bone Joint J*. 2018;100-B(6):822-827. 10.1302/0301-620X.100B6.BJJ-2017-0670.R2
7. Farsetti P, Caterini R, Potenza V, Ippolito E. Developmental dislocation of the hip successfully treated by preoperative traction and medial open reduction: A 22-year mean followup. *Clin Orthop*.
8. Wang CW, Wang T-M, Wu KW, Huang SC, Kuo KN. The comparative, long-term effect of the Salter osteotomy and Pemberton acetabuloplasty on pelvic height, scoliosis and functional outcome. *Bone Joint J*. 2016;98-B (8):1145-1150. 10.1302/0301-620X.98B8.37215
9. Gavrankapetanović I, Hadžimehmedagić A, Papović A, Baždar E. Operative treatment and avascular necrosis of the hip development disorder. *Int Orthop*. 2014;38(7):1419-1424. 10.1007/s00264-014-2363-5
10. Tonnis D. *Congenital Dysplasia and Dislocation of the Hip in ¨children and Adults*. Berlin: Springer-Verlag; 1987. 80-290.
11. Kalamchi A. JBJS GM-, 1980 U. *Avascular Necrosis following Treatment of Hip Dislocation*. Citeseer. Published online 1980:876-888.
12. Ayanoglu T, Ataoglu MB, Tokgöz N, Ersöz E, Atalar H, Turanlı S. Assessing the risk of asymptomatic dysplasia in parents of children with developmental hip dysplasia. *Acta Orthopaedica et Traumatologica Turcica*. 2019;53(5):346-350. 10.1016/j.aott.2019.07.002
13. Li Y, Lin X, Liu Y, et al. Effect of age on radiographic outcomes of patients aged 6–24 months with developmental dysplasia of the hip treated by closed reduction. *J Pediatr Orthop B*. 2019:1-7. 28 10.1097/BPB.0000000000000538
14. Malvitz TA, Weinstein SL. Closed reduction for congenital dysplasia of the hip. *J Bone Jt Surg*. 1994;76-A(12):1777-1792. 10.2106/00004623-199412000-00004
15. Clohisy JC, Nunley RM, Curry MC, Schoenecker PL. Periacetabular osteotomy for the treatment of acetabular dysplasia associated with major aspherical femoral head deformities. *J Bone Jt Surg*. 2007;89(7):1417-1423. 10.2106/00004623-200707000-00002
16. Wu K-W, Wang T-M, Huang S-C, Kuo KN, Chen C-W. Analysis of osteonecrosis following pemberton acetabuloplasty in developmental dysplasia of the hip. *J Bone Jt Surgery-American Vol.238*. 2010;92(11):2083-2094. 10.2106/JBJS.I.01320
17. Parcells BW. Pediatric hip and pelvis. *Pediatr Clin North Am*. 2020;67(1):139-152. 10.1016/j.pcl.2019.09.003
18. Thomas CL, Gage JR, Ogden JA. Treatment concepts for proximal femoral ischemic necrosis complicating congenital hip disease. *J Bone Joint Surg Am*. 1982;64(6):817-828. 10.2106/00004623-198264060-00003
19. Ağuş H, Ömeroğlu H, Uçar H, Biçimoğlu A, Tümer Y. Evaluation of the risk factors of avascular necrosis of the femoral head in developmental dysplasia of the hip in infants younger than 18 months of age1. *J Pediatr Orthop B*. 2002;11 (1):41-46. 10.1097/01202412-200201000-00007
20. Aydin A, Kalali F, Yildiz V, Ezirmik N, Aydin P, Dostbil A. The results of Pemberton's pericapsular osteotomy in patients with developmental hip dysplasia. *Acta Orthop Traumatol Turc*. 2012;46(1):35-41. 10.3944/AOTT.2012.2613
21. Pospischill R, Weninger J, Ganger R, Altenhuber J, Grill F. Does open reduction of the developmental dislocated hip increase the risk of osteonecrosis? *Clin Orthop Relat Res*. 2012;470(1):250-260. 10.1007/s11999-011-1929-4
22. Castañeda P, Masrouha KZ, Ruiz CV, Moscona-Mishy L. Outcomes following open reduction for late-presenting developmental dysplasia of the hip. *J Child Orthop*. 2018;12(4):323-330. 10.1302/1863-2548.12.180078
23. Kotlarsky P. Developmental dysplasia of the hip: What has changed in the last 20 years? *World J Orthop*. 2015;6(11):886. 10.5312/wjo.v6.i11.886