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Hybrid Therapy of Hip-Spica Cast Followed by Static Abduction Orthosis Provides a Similar Successful Outcome as Hip-Spica Cast Only in Infants with Late-Presenting Developmental Dysplasia of the Hip

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ABSTRACT

Objective: This study aims to investigate the therapeutic efficacy of hip-spica casting (HSC) and a hybrid treatment with a static abduction orthosis (SAO) following closed reduction of the hip for treating developmental dysplasia of the hip (DDH), in terms of the acetabular index (AI) and International Hip Dysplasia Institute (IHDI) grade.

Materials and Methods: Patients diagnosed with DDH at a tertiary healthcare center between January 2017 and January 2020 were retrospectively evaluated using post-treatment X-rays. Diagnosis was confirmed through radiography. Twenty hips received HSC treatment for 12 weeks (Group HSC), and 18 hips underwent six weeks of HSC followed by six weeks of SAO treatment (Group SAO). After 12 weeks, AI angles and IHDI scores were collected. Successful treatment was defined as hip reduction achieved without surgical intervention.

Results: The final AI angles for Group HSC and Group SAO were 25.1±3.3 (range: 20–31) and 24.2±2.6 (range: 20–30), respectively (p=0.389). AI improvement was 11.2±3.6 (range: 3–17) degrees for Group HSC and 10.4±3.7 (range: 4.8–17.2) degrees for Group SAO, with both treatment methods showing statistically significant improvements.

Conclusion: Hybrid therapy with static abduction orthosis resulted in comparable improvements in AI angles and IHDI scores, as well as a similar success rate to HSC treatment alone. Replacing HSC treatment partially with SAO could offer advantages, including increased comfort and the elimination of anesthesia requirements.

Keywords: Developmental dysplasia of the hip, orthosis, closed reduction.

INTRODUCTION

Developmental dysplasia of the hip (DDH) is characterized by abnormal development of the hip joint, featuring alterations in the anatomy of the acetabulum and femur. The incidence of DDH ranges from 2 to 6.6 per 1,000 newborns.[1,2] The primary objective of treating DDH is to ensure the normal anatomical development of the acetabulum by achieving a concentrically reduced hip joint, thereby preventing future disabilities. If left untreated, DDH is responsible for approximately 25% of total hip replacements.[3,4]

Various stabilization techniques exist, each with its own set of advantages and disadvantages. Given the current research, it is impossible to recommend a specific treatment. However, closed reduction and hip spica casting (CR-HSC) is emerging as a viable treatment option for patients with late-diagnosed DDH, as recent literature indicates an 83% success rate in achieving concentric reduction.[5,6] Despite these advantages, CR treatment has several drawbacks, including its long duration (12 weeks), patient non-compliance, risk of pressure sores, and difficulties in handling, bathing, hygiene, and transporting infants.[7,8] Additionally, the rapid growth of patients in this age group necessitates cast changes during the treatment period. These modifications, performed under general anesthesia, pose additional risks to the patient and increase medical expenses.[9,10]

Given the aforementioned drawbacks, the search for an optimal stabilization technique continues. A recent systematic review reported a 93% success rate with static abduction orthosis,[11] suggesting that it may be a promising alternative to CR-HSC.

This study aimed to compare the treatment efficacy of using static abduction orthosis partially after a six-week hip spica cast to that of the conventional 12-week hip spica casting, utilizing radiological parameters of DDH. It tested the hypothesis that comparable therapeutic efficiency could be achieved with a hybrid treatment model, offering a more comfortable setting for patients, as measured by radiological parameters of DDH.

MATERIALS AND METHODS

This non-randomized study was conducted at a single tertiary care center. It enrolled patients diagnosed and treated for DDH with CR-HSC between June 2017 and December 2020. The Erciyes University local ethics committee approved the study on January 24, 2017 (201717- 96682346).

Inclusion Criteria

1. Patients diagnosed with late-presenting DDH (defined as a diagnosis after three months of age).
2. No history of previous treatment for DDH.

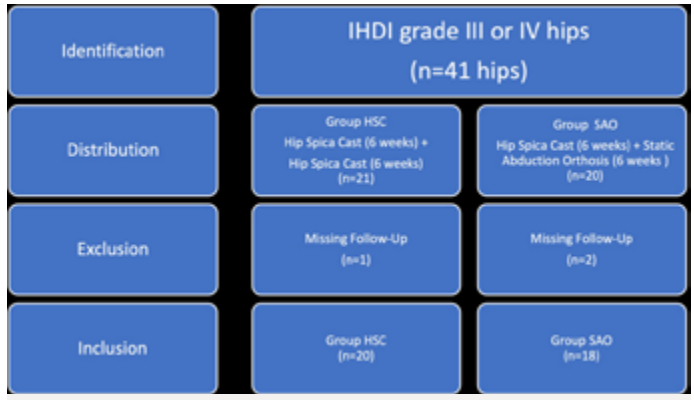

Figure 1. Flow diagram of the study participants.

3. Presence of hip subluxation/dislocation (International Hip Dysplasia Institute [IHDI] classification ≥ grade II).[12]
4. Patients whose hips were successfully reduced with CR, followed by immobilization in a bilateral long leg hip spica cast.

Exclusion Criteria

1. Teratological hip dislocations concurrent with skeletal deformities or metabolic syndromes.
2. Significant language barriers or communication problems affecting treatment quality.
3. Legal guardians who refused to give informed consent.
4. Incomplete medical and radiographic data.

A flowchart diagram of the study is shown below (Fig. 1).

After confirming patient eligibility based on the inclusion/exclusion criteria and obtaining informed consent, patients were allocated to one of two treatment groups: Group SAO (patients treated with static abduction orthosis) and Group HSC (patients treated with a hip spica cast). According to the study protocol, all patients with late-diagnosed DDH included in the study initially underwent CR and were immobilized with a hip spica cast for six weeks (CR-HSC); concentric reduction was confirmed via arthrogram and C-arm fluoroscopy in both treatment groups. At six weeks, hip reduction was re-evaluated using arthrogram and C-arm fluoroscopy. Immobilization was maintained with a hip spica cast for patients in the HSC group, while a static abduction orthosis was applied for patients in the SAO group.

All patients followed a preconstructed treatment protocol. At the end of three months, data from eligible patients were collected for post-interventional measurements. Failure was defined as having an IHDI grade of 3 or 4 in the

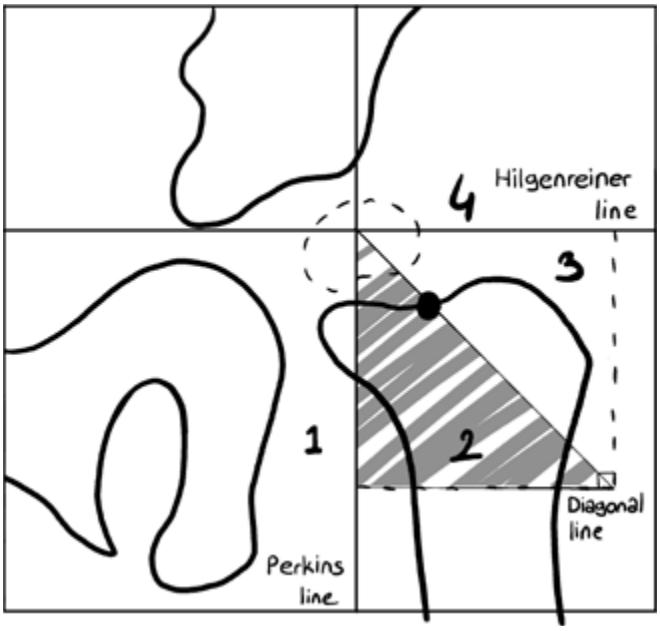

Figure 2. Illustration of the IHDI (International Hip Dysplasia Institute) classification on plain radiography. The H-point (black dot) corresponds to the middle of the proximal femur. The location of the H-point determines the IHDI grade. Grades (I, II, III, and IV) are scored based on the space where the H-point is located.

hip, and/or the necessity for open reduction. One patient in the HSC group and one in the SAO group (bilateral DDH, two hips excluded) did not attend their scheduled follow-ups and were out of reach. Therefore, three hips from two patients were excluded from the statistical analysis. In total, 38 hips from 31 patients were included in the statistical analysis.

Radiographic Outcome Measures

Acetabular Index (AI) Angle

The acetabular index is a quantitative tool used to assess the severity of the condition and the effectiveness of the treatment.[13,14] Measurements are made from coronal plane radiography. The Obturator Index (OI) was defined to standardize optimal positioning, with an OI between 0.56 and 1.80 considered suitable.[15] A horizontal line is drawn connecting the triradiate cartilages, and another line bisecting the inferomedial and superolateral edges of the acetabulum. The angle between these two lines corresponds to the AI angle. AI angle scores for all patients were recorded both pre-intervention and post-intervention.

International Hip Dysplasia Institute (IHDI) Classification

The IHDI classification assesses the severity of hip dysplasia based on the position of the proximal femur, using the midpoint of the proximal femoral metaphysis (H - point) as a reference, which is applicable for children of all ages. In the appropriate coronal plane radiography, Hilgenreiner's line (top of the triradiate cartilage bilaterally), Perkin's line (a line perpendicular to Hilgenreiner's line passing through the superolateral margin of the acetabulum), and the Diagonal line (drawn at a 45-degree angle from the junction of Hilgenreiner's and Perkin's lines) are used.[12] The position of the H-point relative to these lines determines the IHDI grade. IHDI scores for all patients were recorded both pre-intervention and post-intervention (Fig. 2).

Statistical Package for the Social Sciences (SPSS) Statistics software, Version 22.0 (IBM Corp., New York) was used for statistical analysis. P-values less than 0.05 were deemed statistically significant. The sample size prediction was based on previous similar studies. Normal distributions were assessed using the Shapiro–Wilk test. Data were presented as median (minimum and maximum) or numbers (percentage). Between-group comparisons were conducted using the Student's t-test for variables that followed a parametric distribution, and the Mann-Whitney U test for those with a non-parametric distribution.

RESULTS

A total of 38 hips from 31 patients were included in the study. Specifically, 20 hips from 16 patients were treated with a hip spica cast (Group HSC), and 18 hips from 15 patients were treated with static abduction orthosis (Group SAO) during the second period of immobilization. During the study duration, three hips were excluded from the study, indicating a 7% drop-off rate.

The overall age at the time of initial treatment was 4.4±0.6 (range: 4–6) months for Group HSC and 5.2±1.8 (range: 3–9) months for Group SAO, respectively (p=0.167). No statistically significant differences were observed between the two groups in terms of the side of the pathology (right/left) (p=0.360), gender (p=0.167), and pre-intervention IHDI score (p=0.426).

The initial AI angle was 36.2±3.8 (range: 28–42) for Group HSC and 34.7±4.6 (range: 28–44) for Group SAO (p=0.252). Following the 12-week treatment protocol, the AI angle improved to 25.1±3.3 (range: 20–31) in Group HSC and 24.2±2.6 (range: 20–30) in Group SAO (p=0.389). The mean AI improvement was 11.2±3.6 (range: 3–17) in Group HSC and 10.4±3.7 (range: 4.8–17.2) in Group SAO. When both groups were evaluated separately, the improvement in AI angle was statistically significant within each group (p=0.001), and there was no statistically significant difference between the groups in terms of AI angle change (p=0.535) (Table 1).

Table 1. Demographic and preoperative features of the patients

	Group HSC (hip spica cast) (n=20)	Group SAO (static abduction orthosis) (n=18)	p-value (between groups)
Side (right/left)	10/10	7/11	0.360
Gender (male/female)	1/19	0/18	0.526
Birth order	2.1±0.7 (1–4)	2±0.7 (1–3)	0.806
Age (months)	4.4±0.6 (4–6)	5.2±1.8 (3–9)	0.167
Pre-intervention IHDI score	2.6±0.5 (2–3)	2.4±0.5 (2–3)	0.426
Post-intervention IHDI score	1.2±0.4 (1–2)	1.1±0.2 (1–2)	0.460
Pre-intervention AI	36.2±3.8 (28–42)	34.7±4.6 (28–44)	0.252
AI Improvement (difference between pre- and post-intervention measurements)	**11.2±3.6 (3–17)**	**10.4±3.7 (4.8–17.2)**	0.535
Post-intervention AI	25.1±3.3 (20–31)	24.2±2.6 (20–30)	0.389
Necessity for open reduction (present/absent)	3/17	1/17	0.344
IHDI score improvement	1.4±0.5 (1–2)	1.3±0.5 (1–2)	0.965

AI: Acetabular index angle; IHDI: International hip dysplasia institute. The p-value column represents the statistical analysis results between groups. An arrow indicates a statistically significant improvement within the group.

The initial mean IHDI scores were 2.6±0.5 (range: 2–3) for Group HSC and 2.4±0.5 (range: 2–3) for Group SAO. At the final assessment time point, four hips (three in Group HSC and one in Group SAO) demonstrated inadequate reduction and underwent open reduction. The success rate was 95% for the static abduction group and 85% for the CR-HSC group (p=0.287), with an overall success rate of 89%.

Subgroup analysis revealed that the mean pre-intervention AI angle (39.0±2.16) of hips requiring open reduction due to treatment failure was significantly greater than that of hips (35.1±4.23) successfully treated with the closed reduction method (p=0.023) (Table 2).

Table 2. Initial mean AI angles of patients who required open reduction and others

	Pre-interventional AI
Open reduction +	39.0±2.16
Open reduction -	35.1±4.23
P value	0.023

AI: Acetabular index angle.

DISCUSSION

The hybrid treatment protocol provided comparable improvements in AI angle and IHDI scores compared to conventional hip spica casting, as hypothesized. Both groups exhibited significant improvement in AI angle values (p=0.001). Patients who experienced treatment failure exhibited significantly higher initial AI angle values (p=0.023).

There is no globally accepted guideline for the treatment of DDH, with variations in treatment duration, immobilization techniques, and follow-up criteria.[16–18] Surgeons tailor their practice to individual patient characteristics due to the lack of high-quality studies that could help shape an optimal treatment modality. CR-HSC is especially preferred for late-diagnosed DDH. The infant hip is positioned in a 'safe zone' within 100° of flexion and no more than 60° of abduction, as defined by Ramsey, and is mostly preferred by surgeons for patients aged three months and older.[16,17,19] Regardless of the stabilization material used, open reduction should be considered for all children who fail to achieve stable concentric reduction of the hip joint by less invasive techniques, regardless of age.[20]

The treatment process for DDH can be exhausting for infants and their families, largely due to hip spica casting. In a recent study, families reported significant difficulty in not being able to cuddle their children as they wished when using orthotic braces, a challenge that is exacerbated by the hip spica cast and hinders parental bonding.[21] The hybrid abduction orthosis aims to make DDH treatment more manageable and comfortable for both physicians and families without compromising radiologic outcomes. Additionally, replacing the second application of a hip spica cast eliminates the need for a second anesthesia and alleviates discomfort related to the static spica cast.[22]

The acetabular index angle is a valuable radiologic measure that represents acetabular coverage and is frequently used for both diagnosis and monitoring treatment outcomes, including the prediction of late residual dysplasia.[14,23] Although there is a wide range of AI angle variability among children, our goal is to compare absolute improvement. In our study, the mean AI angle at the third-month timestamp was 25.1±3.3 degrees (range: 20–31) for Group HSC and 24.2±2.6 (range: 20–30) for Group SAO. The mean improvement was 11.2±3.6 degrees (range: 3–17) in Group HSC and 10.4±3.7 (range: 4.8–17.2) in Group SAO (p=0.535). Statistically significant AI improvement was observed within both groups; however, the degree of improvement was not statistically significant between them. This indicates that a similar healing process occurred with the use of static abduction orthosis. These results corroborate the findings of a multicenter prospective cohort study by Sankar et al.,[23] where the mean AI angle at the final follow-up (median 22 months; range: 12 to 36 months) was 25 degrees (±6 degrees). We attribute our earlier attainment of similar AI angles to the lower initial IHDI score and a milder DDH cohort in our study. The current study demonstrated that similar AI angle improvements were obtained with our hybrid treatment protocol.

The success rates at the three-month mark following the initial treatment were found to be 85% for Group HSC and 94% for Group SAO, respectively, in the current study (p=0.344). Sankar et al.[23] reported a 91% success rate in a prospective multicenter study using CR-HSC, at a median of eight months after the initial treatment. Similarly, Walter et al.[24] treated 73 hips with CR-HSC as the first line of treatment and confirmed the reduction via magnetic resonance imaging (MRI), counting inadequate reduction in MRI as failure and reporting an 88% success rate. The success rate for static abduction orthosis was reported to be between 79–99%,[25–27] and a recent systematic review stated a 93% overall success rate in children treated with static abduction orthosis.[28] However, the average age at the initiation of treatment was 7.5 weeks (range: 1–19), which is quite early compared to our study, yet the authors reported a similar overall success rate to ours. In contrast, Gou et al.[29] documented a success rate of 65.1% with the human position brace. Although this is lower than what is reported in the literature, the brace group still had a significantly higher success rate, especially in children aged four to six months. The observed discrepancy can be related to the presence of dislocated hips throughout their cohort and the lack of adequate stabilization provided by the hip spica cast. Currently, up to 20% of European Paediatric Orthopaedic Society (EPOS) and Pediatric Orthopaedic Society of North America (POSNA) members prefer static abduction orthosis, according to a recent study, with this preference projected to increase.[17] Consistent with the literature, our hybrid treatment protocol utilizing an abduction brace demonstrated comparable success rates to CR-HSC.

Literature varies on the rates of failed initial reduction for CR-HSC, ranging between 6% and 25%, and up to 7% for static abduction orthosis.[11,23,30] Inoue et al.[31] showed that a pre-treatment AI angle of 36 degrees or more and initial treatment at four months of age or older were associated with treatment failure. In line with these findings, our subgroup analysis of failed hips revealed that initial mean AI angles were significantly higher than in successful cases (39.0±2.16 vs. 35.1±4.23, p=0.023). The slightly higher rate of treatment failure in our study may be attributed to the advanced age at treatment onset and the presence of high initial AI angles.

This study has several limitations, including the late onset of initial treatment age, variability in the grade of dysplasia, and the risk of bias associated with the lack of a universal definition of a good outcome. Additionally, this study focused on a short-term follow-up period, potentially obscuring long-term complications such as residual dysplasia and avascular necrosis (AVN). As the follow-up time extends, higher complication and failure rates are expected. Hence, our success rates likely decreased as we had longer follow-up times for late complications to arise.

CONCLUSION

Patients treated with a combination of static abduction orthosis and hip spica cast demonstrated comparable success rates and similar AI angle improvement to those treated with closed reduction and hip spica cast. Given the additional advantages of eliminating the requirement for general anesthesia and significantly increasing comfort levels, abduction orthosis might be considered a valuable alternative to the second part of hip spica casting.

Ethics Committee Approval: The Erciyes University Clinical Research Ethics Committee granted approval for this study (date: 24.01.2017, number: 201717- 96682346).

Author Contributions: Concept – MO; Design – YUC; Supervision – MO, IHK; Resource – MO, IHK; Materials – RIO; Data Collection and/or Processing – RIO; Analysis and/or Interpretation – RIO, MO; Literature Search – YUC, MO; Writing – YUC, MO; Critical Reviews – HIK.

Conflict of Interest: The authors have no conflict of interest to declare.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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REFERENCES

1. Chand S, Aroojis A, Pandey RA, Johari AN. The incidence, diagnosis, and treatment practices of Developmental Dysplasia of Hip (DDH) in India: A scoping systematic review. Indian J Orthop 2021; 55(6): 1428–39.
2. Pollet V, Percy V, Prior HJ. Relative risk and incidence for developmental dysplasia of the hip. J Pediatr 2017; 181: 202–7.
3. Engesaeter LB, Furnes O, Havelin LI. Developmental dysplasia of the hip--good results of later total hip arthroplasty: 7135 primary total hip arthroplasties after developmental dysplasia of the hip compared with 59774 total hip arthroplasties in idiopathic coxarthrosis followed for 0 to 15 years in the Norwegian Arthroplasty Register. J Arthroplasty 2008; 23(2): 235–40.
4. Thillemann TM, Pedersen AB, Johnsen SP, Søballe K; Danish Hip Arthroplasty Registry. Implant survival after primary total hip arthroplasty due to childhood hip disorders: results from the Danish Hip Arthroplasty Registry. Acta Orthop 2008; 79(6): 769–76.
5. Bian Z, Guo Y, Tian W. Treatment of developmental dysplasia of the hip in children: results of closed reduction and immobilization in hip spica cast. Zhonghua Wai Ke Za Zhi 2009; 47(13): 1017–9.
6. Zhang G, Li M, Qu X, Cao Y, Liu X, Luo C, et al. Efficacy of closed reduction for developmental dysplasia of the hip: midterm outcomes and risk factors associated with treatment failure and avascular necrosis. J Orthop Surg Res 2020; 15(1): 579.
7. McHale KA, Corbett D. Parental noncompliance with Pavlik harness treatment of infantile hip problems. J Pediatr Orthop 1989; 9(6): 649–52.
8. Gather KS, von Stillfried E, Hagmann S, Müller S, Dreher T. Outcome after early mobilization following hip reconstruction in children with developmental hip dysplasia and luxation. World J Pediatr 2018; 14(2): 176–83.
9. Demir SG, Erden S, Bulut H, Carboga B, Elbas NO.The problems experienced by parents providing postoperative home care following their child's surgery for developmental dysplasia of the hip. Orthop Nurs 2015 34(5): 280-6; quiz 287–8.
10. Pisecky L, Großbötzl G, Gahleitner M, Haas C, Gotterbarm T, Klotz MC. Results after spica cast immobilization following hip reconstruction in 95 cases: is there a need for alternative techniques?. Arch Orthop Trauma Surg 2022; 142(6): 969–77.
11. Pavone V, de Cristo C, Vescio A, Lucenti L, Sapienza M, Sessa G, et al. Dynamic and static splinting for treatment of developmental dysplasia of the hip: a systematic review. Children (Basel) 2021; 8(2): 104.
12. Narayanan U, Mulpuri K, Sankar WN, Clarke NM, Hosalkar H, Price CT; International hip dysplasia institute. reliability of a new radiographic classification for developmental dysplasia of the hip. J Pediatr Orthop 2015; 35(5): 478–84.
13. Li Y, Guo Y, Li M, Zhou Q, Liu Y, Chen W, et al; Multi-center Pediatric Orthopedic Study Group of China. Acetabular index is the best predictor of late residual acetabular dysplasia after closed reduction in developmental dysplasia of the hip. Int Orthop 2018; 42(3): 631–40.
14. Shin CH, Yang E, Lim C, Yoo WJ, Choi IH, Cho TJ. Which acetabular landmarks are the most useful for measuring the acetabular index and center-edge angle in developmental dysplasia of the hip? a comparison of two methods. Clin Orthop Relat Res 2020; 478(9): 2120–31.
15. Tönnis D. Normal values of the hip joint for the evaluation of X-rays in children and adults. Clin Orthop Relat Res 1976; (119): 39–47.
16. Al-Essa RS, Aljahdali FH, Alkhilaiwi RM, Philip W, Jawadi AH, Khoshhal KI. Diagnosis and treatment of developmental dysplasia of the hip: A current practice of paediatric orthopaedic surgeons. J Orthop Surg (Hong Kong) 2017; 25(2): 2309499017717197.
17. Alves C, Truong WH, Thompson MV, Suryavanshi JR, Penny CL, Do HT, et al. Diagnostic and treatment preferences for developmental dysplasia of the hip: a survey of EPOS and POSNA members. J Child Orthop 2018; 12(3): 236–44.
18. Feeley IH, Green CJ, Rowan FE, Moore DP. International variance in the treatment of developmental dysplasia of the hip. J Child Orthop 2014; 8(5): 381–6.
19. Ramsey PL, Lasser S, MacEwen GD. Congenital dislocation of the hip. Use of the Pavlik harness in the child during the first six months of life. J Bone Joint Surg Am 1976; 58(7): 1000–4.
20. Zamzam MM, Kremli MK, Khoshhal KI, Abak AA, Bakarman KA, Alsiddiky AM, et al. Acetabular cartilaginous angle: a new method for predicting acetabular development in developmental dysplasia of the hip in children between 2 and 18 months of age. J Pediatr Orthop 2008; 28(5): 518–23.
21. Grzybowski G, Bliven E, Wu L, Schaeffer EK, Gibbard M, Zomar BO, et al. caregiver experiences using orthotic treatment options for developmental dysplasia of the hip in children. J Pediatr Orthop 2023; 43(2): 105–10.
22. Olsen EA, Brambrink AM. Anesthesia for the young child undergoing ambulatory procedures: current concerns regarding harm to the developing brain. Curr Opin Anaesthesiol 2013; 26(6): 677–84.

23. Sankar WN, Gornitzky AL, Clarke NMP, Herrera-Soto JA, Kelley SP, Matheney T, et al; International Hip Dysplasia Institute. Closed reduction for developmental dysplasia of the hip: early-term results from a prospective, multicenter cohort. J Pediatr Orthop 2019; 39(3): 111–8.
24. Walter SG, Endler CH, Remig AC, Luetkens JA, Bornemann R, Placzek R. Risk factors for failed closed reduction in dislocated developmental dysplastic hips. Int Orthop 2020; 44(11): 2343–8. Erratum in: Int Orthop 2021; 45(11): 3009.
25. Eberle CF. Plastazote abduction orthosis in the management of neonatal hip instability. J Pediatr Orthop 2003; 23(5): 607–16.
26. Hedequist D, Kasser J, Emans J. Use of an abduction brace for developmental dysplasia of the hip after failure of Pavlik harness use. J Pediatr Orthop 2003; 23(2): 175–7.
27. Sankar WN, Nduaguba A, Flynn JM. Ilfeld abduction orthosis is an effective second-line treatment after failure of Pavlik harness for infants with developmental dysplasia of the hip. J Bone Joint Surg Am 2015; 97(4): 292–7.
28. Wahlen R, Zambelli PY. Treatment of the developmental dysplasia of the hip with an abduction brace in children up to 6 months old. Adv Orthop 2015; 2015: 103580.
29. Gou P, Zhang Y, Wu J, Li J, Li X, Li M, et al. human position brace versus pavlik harness for infants under 6 months of age with developmental dislocation of the hip: a comparison of therapeutic efficacy. J Pediatr Orthop 2021; 41(7): e545–9.
30. Cooper AP, Doddabasappa SN, Mulpuri K. Evidence-based management of developmental dysplasia of the hip. Orthop Clin North Am 2014; 45(3): 341–54.
31. Inoue T, Naito M, Nomiyama H. Treatment of developmental dysplasia of the hip with the Pavlik harness: factors for predicting unsuccessful reduction. J Pediatr Orthop B 2001; 10(3): 186–91.