Acta Orthop. Belg., 2016, **82**, 843-849

ORIGINAL STUDY

Lower limb equalization with percutaneus epiphysiodesis of the knee joint area

Kryspin Niedzielski, Pawel Flont, Marcin Domżalski, Zbigniew Lipczyk, Krzysztof Malecki

From Clinic of Orthopedic and Traumatology, Polish Mother's Memorial Hospital Research Institute, Lodz, Poland

Introduction **: Epiphysiodesis has become one of the most popular methods in the treatment of leg length discrepancy (LLD) due to its surgical simplicity, short hospitalization time, and a low risk of complications.**
Patients and Methods **: A retrospective analysis was performed on 34 patients treated for LDD with percutaneus epiphisiodesis of the distal femur and/or the proximal tibia. The mean discrepancy was 2.8 cm. The outcome evaluation method was based on Kemnitz *et al*.**
Results **: Based on the Kemnitz criteria, 23 (67.6%) patients experienced good results, while 2 (5.9%) satisfactory and 9 (26.5%) poor results. In 47% of patients, swellings of the knee joint were observed in the postoperative period. One serious complication – varus deformity of 10 degrees in femur occurred in the follow-up period.**
Conclusions **: Percutaneous epiphysiodesis is a simple method of the LLD correction, with a low rate of complications and applicable in cases of late LDD diagnosis.**

Keywords : leg length discrepancy, percutaneous epiphysiodesis, timing of epiphysiodesis.

INTRODUCTION

Leg length discrepancy (LLD) is a common problem in pediatric orthopedics. The choice of treatment is based on the patient's age, the etiology of the lower limb discrepancy and the expected LLD at the completion of skeletal growth. Successful treatment depends mainly on choosing a route combining the precise correction of deformity with a minimal risk of complications. A surgical correction of the LLD may be achieved by a temporary or permanent epiphysiodesis, distractive osteogenesis or the shortening of a longer leg *(1)*.

Epiphysiodesis has become one of the most popular methods for the treatment of LLD *(13,15,18,29)* due to its surgical simplicity, short hospitalization time, and a low risk of complications. Epiphysiodesis is recommended for the children whose bones are growing, with an expected LLD ranging between 2

No benefits or funds were received in support of this study. The authors report no conflict of interests.

■ Kryspin Niedzielski, Ph.D., M.D.
■ Paweł Flont, Ph.D., M.D.
■ Zbigniew Lipczyk, Ph.D., M.D.
■ Krzysztof Malecki, Ph.D., M.D.
Clinic of Orthopedic and Traumatology, Polish Mother's Memorial Hospital Research Institute, Poland
■ Marcin Domzalski, Ph.D., M.D.
Orthopaedic and Trauma Department, Medical University of Lodz, Poland, Veteran's Memorial Teaching Hospital in Lodz.
Correspondence : Pawel Flont, Rzgowska 281/289, Lodz, Poland.
E-mail : flont2002@yahoo.com

and 5 cm. *(15,18)*. Although the surgical procedure is simple, a proper preoperative planning is of crucial importance. Based on the actual and expected LLD at the end of the growth, a suitable age for the surgery is established as well as localization and a number of growth plates to be blocked *(2,11,18,24,25)*.

The aim of our study is to assess the long-term results of percutaneous epiphysiodesis at the knee level.

PATIENTS AND METHODS

We reviewed all patients with LLD treated between 1994 and 2007 at our institution and chose only those with percutaneous epiphysiodesis of the knee joint area (55 children). In total, 34 patients, 16 girls and 18 boys, who were available for the follow-up examination, were retrospectively analyzed. The average age at the time of surgery in girls was 12.2 years (range: 10 to 14 years, SD 1.05) and 13.2 years in boys (range: 11 to 14, SD 1). The average LLD at the time of surgery was 2.8 cm (range: 2.0 to 4.5 cm). The mean follow-up time was 4 years (range: 2 to 8 years). The most common etiology of LLD was acute hematogenous osteomyelitis in infants and toddlers and trauma (Table I).

The patients were qualified for percutaneous epiphysiodesis according to the criteria offered by Eastwood and Cole *(11)* regarding the timing and level of epiphysiodesis, with different graphs used for boys and girls. The discrepancy in length was assessed clinically using a measuring tape and X-ray (Fig. 1, 2A, 2B). Demographic and preoperative clinical data was obtained from the patients' medical records. Of the 34 patients who met the study, 17 underwent a distal femoral epiphysiodesis, distal femoral and a 15 proximal tibial epiphysiodesis and 2 proximal tibia epiphysiodesis (Table II).

The surgical procedure was performed under general anesthesia with the patient in the supine position without tourniquet. One-cm-long-skin incisions were performed medially and laterally at the level of the distal femoral growth plate under fluoroscopic guidance. The growth plate was reached through this incision and using a surgical spoon, the proper amount of cartilage was removed, mainly from the central portion of the growth plate,

Table I. — Causes of the leg length discrepancy

Etiology of the leg length discrepancy	Number
Osteomyelitis	14
Trauma	9
Tibial Hypoplasia	3
Legg-Calvé-Perthes disease	3
Club-foot	2
Developmental dysplasia of the hip	2
Slipped capital femoral epiphysis	1

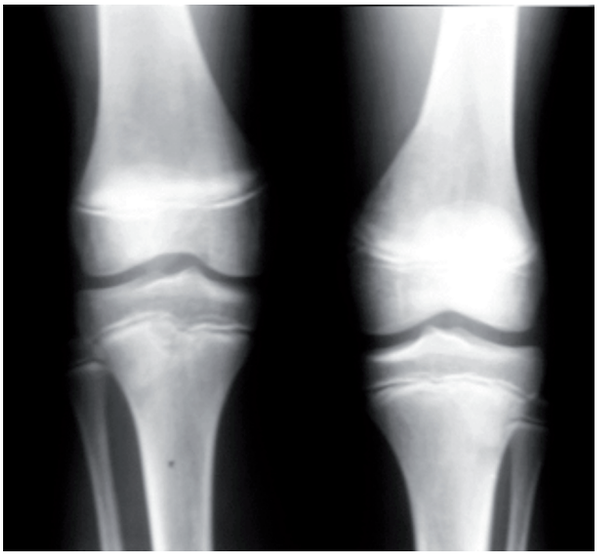

Fig. 1. — Preoperative X-ray picture of the knee joint in AP projection showing the shortening of the right lower limb in the patient planned for femur and tibia epiphysiodesis?

as well as a tiny layer of spongious bone from the epiphysis and metaphysis. The proximal growth plate of the tibia was removed in the same manner using a single medial incision (Fig. 3A, 3B). In selected cases an additional lateral approach was used to assure complete removal of the cartilage *(13,15)*. The postoperative regimen comprised isometric exercises followed by active motion of the knee joint during the two postoperative days. Walking on crutches was allowed on the next post-op day but with no weight bearing on the affected leg. Partial weight-bearing was allowed on the operated leg after pain subsided, and full weight-bearing was permitted 3 weeks after surgery. The outcomes were evaluated radiographically using

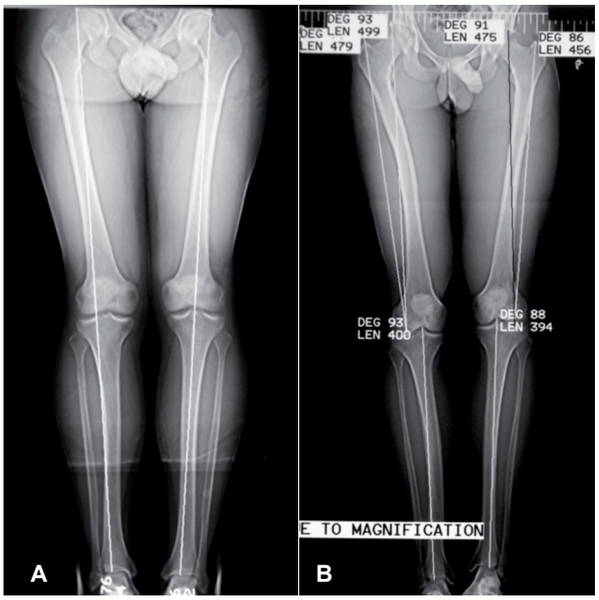

Fig. 2. — X-rays done for an accurate LLD measure, assessing possible axial deformity and physeal closure 2A. Patient with full correction 2B. Patient with 23mm femur and 6mm tibia shortening.

X-ray images of the affected leg and by functional assessments: measurements of the length and axis of the leg. X- rays were performed in the operating theater immediately after surgery and then 3 weeks, 3 months and 6 months after surgery in standard antero-posterior and lateral projections. Fusion of the growth plates was assessed on these radiograms. After surgery, 34 of the 55 operated children were subsequently followed-up every 6 months in the outpatient clinic until the end of their growth. The contralateral growth plate closure in the knee X-ray was considered as a sign of the end of growth. The assessment of the final results of the leg length measurements was based on the Kemnitz criteria: leg length discrepancy up to 1.5 cm gives a good result, between 1.5 to 2 cm gives a satisfactory outcome and longer than 2 cm is considered to be a poor result *(18)*.

RESULTS

According to the Kemnitz criteria, a good outcome was found in 23 (67.6%) cases, satisfactory in 2 (5.9%) and poor in 9 (26.5%) patients. Further analysis of the poor results observed at the end of the growth revealed that LLD ranged from 2.1 to 4.0 cm, with 2.9 cm on average (SD 0.6, median value 3). 3 cm over-correction was noted in one patient while under-correction of the limb length discrepancy was observed in others (Table II).

The most common complication seen in the early postoperative period was edema of the knee, observed in 47.9% cases. This edema was associated with pain and limited motion of the knee joint. Three to 6 days post-op, the edema subsided spontaneously and a rehabilitation protocol was started. Only in 1 case did edema last 3 weeks, which disturbed rehabilitation, leading to a significant limitation of the range of motion of the knee joint. In this case, mobilization under general anesthesia was performed with subsequent intensive rehabilitation. The final outcome in this child was good with an unlimited, painless range of motion of the knee. One serious complication - varus deformity of 10 degrees in femur at the end of growth due to the incomplete destruction of the lateral portion of the growth plate – occurred in the late follow-up period. Neither inflammatory (septic arthritis), neurological nor vascular complications were observed in this population.

DISCUSSION

First epiphysiodesis was performed by Phemister in an open way. The disadvantages of this technique included long hospitalization time, pain in the place of surgery, scars and irreversibility. Hence it was a predictable method of making a bone bridge in the growth plate during the procedure performed without fluoroscopy *(26)*.

This technique is no longer used because permanents epiphysiodesis is performed in a closed manner. The advantages of this procedure include short hospitalization time, a small scar and fast recovery process, while almost no complications were observed *(5,12,15,17-18,27,29,31)*. Yet arterial pseudoaneurysm, nerve injury or creation of an exostosis in the tibia were noted *(7,32-33)*. This technique is irreversible and if the damage of the growth plate is not symmetrical, the long bone axis may be affected. This is more frequent if femoral epiphysiodesis

Table II. — Details of patients

Case no.	Sex	Age at surgery (years)	Follow-up (years)	LLD at surgery (cm)	LLD at growth end (cm)	Epiphisiodesis localisation. F-femur, T-tibia	Cause of LLD	Comments
1	F	12	5	3.5	1	F	Septic arthritis	
2	M	13	4	2.5	0	F	Septic arthritis	
3	M	12	5	3	0.7	F	Hypoplasia cruris	
4	F	10	6	4.5	1.5	F/T	Septic arthritis	
5	F	12	4	2	0.5	F	Club-foot	
6	M	13	3	2	1	F	Club-foot	
7	F	13	3	2	3.5	F	Posttraumatic	
8	M	14	3	2	0.9	F/T	Posttraumatic	
9	F	13	3	2	1	F/T	Posttraumatic	
10	M	13	4	3	0.5	F/T	Posttraumatic	
11	F	12	6	2.5	1	F	Septic arthritis	
12	M	14	3	3	2.1	F/T	Perthes disease	
13	F	12	5	4	3	F	Septic arthritis	
14	F	11	6	3.5	1	F	Posttraumatic	
15	M	11	8	3.5	+3	F/T	Hypoplasia cruris	Overcorrection
16	F	12	5	3	0.5	F	Septic arthritis	
17	M	13	4	2	1.8	F/T	Slipped capital femoral epiphysis	
18	F	13	3	2.5	0.5	F/T	Septic arthritis	
19	M	14	3	2	0	F	Septic arthritis	
20	F	13	3	2	0.5	F	Posttraumatic	
21	M	13	4	4	1	F/T	DDH	10° varus
22	M	14	3	3	1.5	F/T	Septic arthritis	
23	F	14	2	3	3	F/T	DDH	
24	M	13	3	2	1	F	Posttraumatic	
25	F	11	5	3.5	3	F	Septic arthritis	
26	F	13	3	4.5	4	F/T	Septic arthritis	
27	F	11	5	3	0.5	F	Septic arthritis	
28	M	14	3	4	3	F/T	Posttraumatic	
29	F	13	4	2.5	2	F/T	Perthes disease	
30	M	11	7	4	0.7	T	Hypoplasia cruris	
31	M	14	2	2	1.5	F	Septic arthritis	
32	M	14	3	2	0	T	Septic arthritis	
33	M	14	3	2.5	1.7	F	Posttraumatic	
34	M	14	3	2.5	0.5	F/T	Perthes disease	

is performed with one incision *(12)*. The surgery can be done with a curette, a high speed-bur or a cannulated reamer *(8,29,31)*. The amount of cartilage that has to be damaged is not determined. In comparison to temporal epiphysiodesis, the inhibition of growth occurs immediately after surgery.

Theoretically, a temporary epiphysiodesis can be the optimal method. The correction can be made earlier with no fear of damaging the growth plate. At first Blount staples were used in the procedure *(4)*. This technique requires implantation of 3 implants on each side. This leads to a more invasive surgery with larger scars and longer hospitalization period. The staples have to be placed over periosteum, close to the medial and lateral collateral ligament in the knee and formation of a scar in this region may increase a range of the knee motion. Moreover, the implants sometimes migrate causing breakages or the soft tissue irritation. The affected patients need additional surgery for the implant correction. Afterwards limb equalization staples have to be removed, which is sometimes a big challenge for the surgeons especially if they were placed under periosteum *(10)*. Few authors recommend the removal of Blount staples 2 years after the surgery to not impair the function of the growth plate. The procedure impairs the bone growth 6 months after the implantation *(28)*.

Another rarely used method – epiphysis screw fixation – was developed by Metaizeau *(22)*. This reversible, closed procedure is more technically advanced. The screw has to be placed symmetrically in the central part of epiphysis in AP and the lateral X-ray view is performed to not affect the bone axis. For technical reasons the screw should be placed perpendicularly to the epiphyseal plate but a different option was also described *(22-23)*. The procedure can be minimally invasive, the patient is able to walk right after the surgery. The screw may migrate through some epiphyses, such as the tibial one, due to its small size. One study showed that the use of the PETS technique in the femur was safe, but its use in the tibia was associated with a significant rate of complications (valgus deformity) *(16)*. The skin irritation, decreased knee motion or the implant breakage are rarely observed *(23)*. As for other implants used in epiphysiodesis, deterioration of growth may be observed after 6 month.

In theory, the eight plates procedure should be the best solution for safe, minimally invasive, reversible epiphysiodesis. It was widely and successfully applied in the correction of the bone axis. Recent studies suggest that the double 8-plate placed symmetrically does not impede its growth *(19)*. The study comparing 8-plate with other methods of epihysiodesis show that the growth arrest observed at the follow-up was unpredictable and lower than that achieved with other methods (PETS, percutaneous technique). This study does not recommend the use

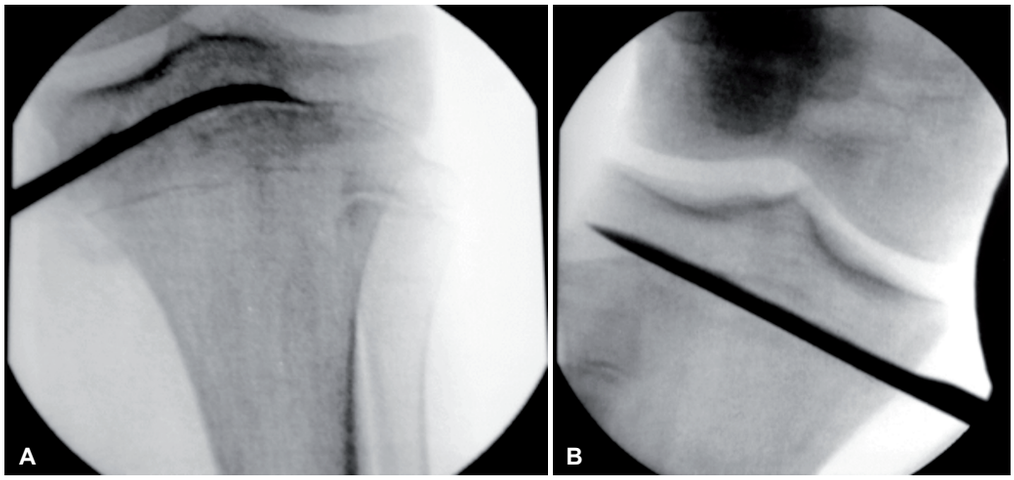

Fig. 3. — Videoprint from epiphysiodesis on the proximal tibia 3A. Initial physeal destruction with a curette 3B. Total physeal destruction

of medial and lateral 8-plates because the median improvement in the limb length discrepancy was only 4 mm *(30)*.

The studies comparing open Phemister and percutaneous techniques show that the fluoroscopic surgery causes much smaller scars, smaller postoperative knee stiffness, and a shorter hospital stay. On the other hand, the two groups show the same frequency of complication (4%) *(20)*.

The other study shows that the percutaneous technique is more effective than the screw fixation as it can produce a reduction in the mean leg-length discrepancy of 2.5 cm against a mean change of 1.8 cm when using the Metaizeau technique. Moreover, fewer complications were found using percutaneous epiphysiodesis as opposed to the percutaneous screw fixation. The time taken to perform each surgery was found to be no different, and the hospital stay was the same *(3)*.

Three operative techniques for epiphysiodesis (Phemister technique, percutaneous drilling, a transphyseal screw) were compared by Campens C et all *(6)*. He showed no statistically significant difference in the correction of a lower limb length discrepancy and a complication rate. Yet percutaneous epiphysiodesis using a transphyseal screw appeared to be the best technique regarding the average operative and hospitalization time as well as recovery period *(6)*.

In our group the main causes of complications were incorrect predictions of the leg length inequality at the end of growth, which resulted in the wrong decisions about timing and level of epiphysiodesis. Such conclusions were presented in the previous studies *(9,18,21,24,34)*. Unfortunately, as it is difficult to make precise predictions about the future growth, no method used to determine the timing of surgical intervention is fully reliable. Even the most popular, complex, and recommended methods such as Green-Anderson charts or Paley "multiplier" method do not guarantee good estimation of the limb length after the skeletal maturity in each case *(14,25)*. Therefore, not only results taken from tables and graphs, but also the cause of LDD, height of the parents and siblings, signs of puberty, nutritional, metabolic, hormonal and socioeconomic factor should be taken into account in the qualification of patients for epiphysiodesis *(1,2,6,21,32)*. In 32.3% cases the procedure failure is due to improper prognosis of epiphysiodesis timing of surgery epiphysiodesis and not the surgery technique itself. Therefore we think the method described above may only be applied in cases of late diagnosis of LDD and as an additional procedure combined with a distraction of the contralateral leg.". At present we have changed our management and began to use temporary epiphysiodesis with Blount staples.

Another important problem associated with epiphysiodesis is the the need to perform surgery on the healthy side. This can represent a psychological barrier for many patients and their parents and requires extensive explanation.

CONCLUSIONS

Percutaneous epiphysiodesis is a simple method of the LLD correction, with a low rate of complications and applicable in cases of late LDD diagnosis. Compared to other methods, this is a predictable, irreversible procedure with immediate deterioration of the bone growth and with no need to remove the implant.

REFERENCES

1. **Amstutz HC, Sakai DN.** Equalisation of leg length. *Clin Orthop* 1978 ; 136 : 2-6.
2. **Anderson M, Green WT, Messner MB.** Growth and predictions of growth in the lower extremities. *J Bone Joint Surg Am* 1963 ; 45(1) : 1-14.
3. **Babu LV, Evans O, Sankar A, Davies AG, Jones S, Fernandes JA.** Epiphysiodesis for limb length discrepancy: a comparison of two methods. *Strategies Trauma Limb Reconstr* 2014 ; 9(1) : 1-3.
4. **Blount W P, Clarke G R.** Control of bone growth by epiphyseal stapling. J Bone Joint Surg 1949 ; 31A : 464-78.
5. **Bowen JR, Johnson WJ.** Percutaneus epiphysiodesis. *Clin Orthop Relat Res* 1984 ; 190 : 170-3.
6. **Campens C, Mousny M, Docquier PL.** Comparison of three surgical epiphysiodesis techniques for the treatment of lower limb length discrepancy. *Acta Orthop Belg* 2010 ; 76(2) : 226-32.
7. **Canale ST, Russell TA, Holcombe RL.** Percutaneous epiphysiodesis: experimental study and preliminary clinical results. *J Pediat Orthop* 1986 ; 6 : 150-156.
8. **Caskey PM, Baird GO, Tompkins BJ, Foley RP.** Single-incision percutaneous epiphysiodesis of the lower extremity. *Oper Tech Orthop* 2009 ; 19 : 31-35.

9. **Dewaele J, Fabry G.** The timing of epiphysiodesis. A comparative study between the use of the method of Anderson and Green and the Moseley chart. *Acta Orthop Belg* 1992 ; 58(1) : 43-47.
10. **Dushan T, Gardiner J.** Technique to Aid Removal of Blount Staples With Minimal Bone Destruction. *Techniques in Orthopaedics* 2013 ; 28(3) : 267.
11. **Eastwood DM, Cole WG.** A graphic method for timing the correction of leg-length discrepancy. *J Bone Joint Surg Br* 1995 ; 77(5) :743-47.
12. **Edmonds EW, Stasikelis PJ.** Percutaneus epiphysiodesis of the lower extremity: a comparison of single – versus double-portal techniques. *J Pediatr Orthop* 2007 ; 27(6) : 618-22.
13. **Gabriel KR, Crawford AH, Roy DR, True MS, Sauntry S.** Percutaneus epiphysiodesis. *J Pediatr Orthop* 1994 ; 14(3) : 358-62.
14. **Green WT, Anderson M.** Epiphyseal arrest for the correction of discrepancies in length of the lower extremities. *J Bone Joint Surg Am* 1957 ; 39(4) : 853-72.
15. **Horton GA, Olney BW.** Epiphysiodesis of the lower extremity: results of the percutaneus technique. *J Pediatr Orthop* 1996 ; 16(2) : 180-82.
16. **Ilharreborde B, Gaumetou E, Souchet P, Fitoussi F, Presedo A, Penneçot GF, Mazda K.** Efficacy and late complications of percutaneous epiphysiodesis with transphyseal screws. *J Bone Joint Surg Br* 2012 ; 94(2) : 270-5.
17. **Inan M, Chan G, Littleton AG, Kubiak P, Bowen JR.** Efficacy and safety of percutaneus epiphysiodesis. *J Pediatr Orthop* 2008 ; 28(6) : 648-51.
18. **Kemnitz S, Moens P, Fabry G.** Percutaneus epiphysiodesis for leg length discrepancy. *J Pediatr Orthop B* 2003 ; 12(1) : 69-71.
19. **Lauge-Pedersen H, Hägglund G.** Eight plate should not be used for treating leg length discrepancy. *J Child Orthop* 2013 ; 7(4) : 285-8.
20. **Liotta FJ, Ambrose TA, Eilert RE.** Fluoroscopic technique versus Phemister technique for epiphysiodesis. *J Pediatr Orthop* 1992 ; 12(2) : 248-51.
21. **Little DG, Nigo L, Aiona MD.** Deficiencies of current methods for the timing of epiphysiodesis. *J Pediatr Orthop* 1996 ; 16(2) : 173-179.
22. **Métaizeau JP, Wong-Chung J, Bertrand H, Pasquier P.** Percutaneus epiphysiodesis using transphyseal screws (PETS). *J Pediatr Orthop* 1998 ; 18(3) : 363-69.
23. **Monier BC, Aronsson DD, Sun M.** Percutaneous epiphysiodesis using transphyseal screws for limb-length discrepancies: high variability among growth predictor models. *J Child Orthop* 2015 ; 9(5) : 403-10.
24. **Moseley CF.** A straight line graph for length discrepancies. *Clin Orthop* 1978 ; 136 : 33-40.
25. **Paley D, Bhave A, Herzenberg JE, Bowen JR.** Multiplier method for predicting limb-length discrepancy. *J Bone Joint Surg Am*. 2000 ; 82 : 1432-46.
26. **Phemister DB.** Operative arrestment of longitudinal growth of bones in the treatment of deformities. *J Bone Joint Surg Am* 1933 ; 15 : 1-15.
27. **Porat S, Peyser A, Robin GC.** Equalization of lower limbs by epiphysiodesis: results of treatment. *J Peditr Orthop* 1991 ; 11(4) : 442-48.
28. **Siedhoff M, Ridderbusch K, Breyer S, Stücker R, Rupprecht M.** Temporary epiphyseodesis for limb-length discrepancy. 8- to 15-year follow-up of 34 children. *Acta Orthop* 2014 ; 85(6) : 626-32.
29. **Stephens DC, Herrick W, MacEwen G.** Epiphysiodesis for limb lenght inequality. *Clin Orthop* 1978 ; 136 : 41-48.
30. **Stewart D, Cheema A, Szalay EA.** Dual 8-plate technique is not as effective as ablation for epiphysiodesis about the knee. *J Pediatr Orthop* 2013 ; 33(8) : 843-6.
31. **Surdam JW, Morris CD, DeWeese JD, Drvaric DM.** Leg length inequality and epiphysiodesis: review of 96 cases. *J Pediatr Orthop* 2003 ; 23(3) : 381-84.
32. **Timperlake R, Bowen JR, Guile JT, Choi IH.** Prospective evaluation of fifty-tree consecutive percutaneous epiphysiodeses of distal femur and proximal tibia and fibula. *J Pediatr Orthop* 1991 ; 11(30) : 350-57.
33. **Wavreille G, Frick L, Cassio JB, Soenen M, Chantelot C, Lecomte F.** A secondary bleeding false aneurysm of the superomedial genicular artery after distal femoral epiphysiodesis: a case report. *Rev Chir Orthop Reparatrice Appar Mot* 2008 ; 94(2) : 193-6.
34. **Westh RN, Menelaus MB.** A simple calculation for the timing of epiphyseal arrest. *J Bone Joint Surg Br* ; 63(1) : 117-119.