The modified Dunn procedure for slipped capital femoral epiphysis: the Bernese experience

M. Tannast[1]
L. M. Jost[1]
T. D. Lerch[1]
F. Schmaranzer[1]
K. Ziebarth[2]
K. A. Siebenrock[1]

Abstract

Purpose Based on previous investigations on the vascular blood supply to the femoral head, a technique for anatomical reduction after slipped capital femoral epiphysis was developed. This technique is a modification of the original technique by Dunn using a retinacular soft-tissue flap. This allows the visual control of the epiphyseal vascular blood supply. We report the experience at the inventor's institution with a critical discussion of the available literature.

Methods Using a trochanteric osteotomy for surgical dislocation of the hip, a retinacular soft tissue flap is created containing the deep branch of the medial femoral circumflex artery, the external rotators and the capsule. The femoral epiphysis can be mobilised safely and reduced on the femoral neck after resection of the almost constantly present reactive metaphyseal callus.

Results In our institution, the rate of avascular necrosis with 2% is comparably low to Dunn's original results. It is only present in cases where no bleeding was already evident before reduction of the epiphysis. The ten-year long-term results are favorable in these cases with a good functional result and only little progression of osteoarthritis. However, other authors have reported higher rates of avascular necrosis up to 24% in their initial experience.

Conclusions In experienced hands using the correct meticulous surgical technique, the results are favorable regarding the rates of avascular necrosis, the functional outcome and

[1] Department of Orthopaedic Surgery, Inselspital, Bern University Hospital, University of Bern, 3010 Bern, Switzerland
[2] Department of Pediatric Orthopaedics, Inselspital, Bern University Hospital, University of Bern, 3010, Bern, Switzerland

Correspondence should be sent to: Moritz Tannast, MD, Department of Orthopaedic Surgery, Inselspital, Freiburgstrasse, 3010 Bern, Switzerland
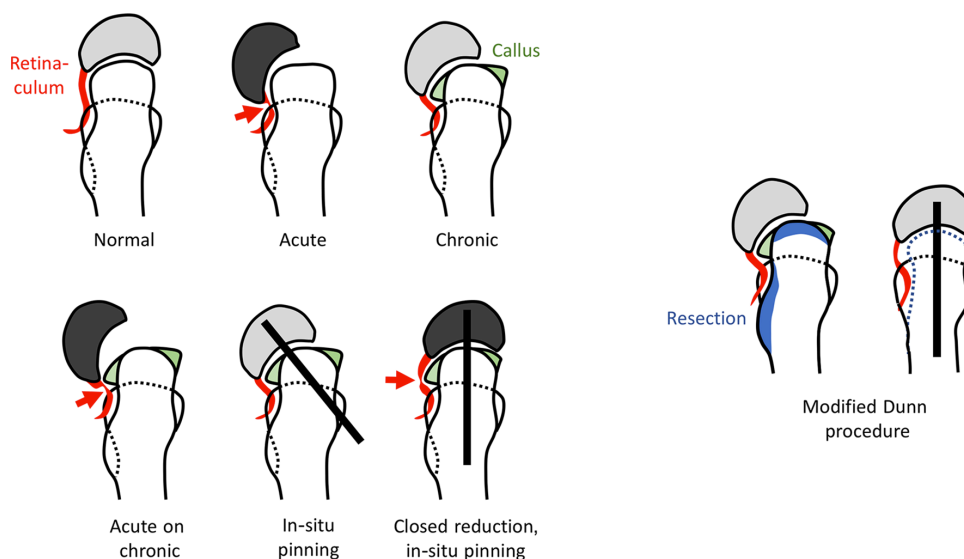E-mail: moritz.tannast@insel.ch

the development of radiographic osteoarthritis – even in acute and severe cases. Avascular necrosis is rare but can be observed if there is no evidence of intra-operative femoral head perfusion before and after reduction of the epiphysis.

Introduction

The treatment of slipped capital femoral epiphysis (SCFE) has been controversial for decades. It is in the nature of things that an anatomical reduction of the epiphysis provides the best condition for a good function of the hip joint in the long-term – given a surgical technique that can control the blood supply to the femoral head. The attempts to anatomically reduce the femoral epiphysis by a subcapital reorientation with an anterior approach in the mid of the last century have resulted in rates of avascular necrosis (AVN) up to 54%.[1,2] In 1964, Dunn presented a promising technique of subcapital reorientation through a posterior approach with a trochanteric osteotomy with a risk of avascular necrosis of only 4%.[3] Similar to the observations in the last 15 to 20 years in our institution, Dunn pointed out that a callus formation at the posterior aspect of the femoral neck is present in most of the cases.[4] This callus formation can neither be seen nor addressed from anteriorly or through a closed reduction maneuver. This can explain the high AVN rate with these techniques, since the typically shortened retinacular vessels in SCFE are stretched and may be occluded when the epiphysis is reduced. He pointed out that a careful subperiosteal preparation of the retinacular vessels with a resection of the newly formed callus and some neck shortening is the key to preserve the blood supply to the femoral head (Fig. 1). Many authors have tried to reproduce Dunn's results. However, they report substantially higher rates of AVN up to 54%,[1] and the technique has not found a wide distribution.

Fig. 1 Overview of different conditions in slipped capital femoral epiphysis (SCFE). In the acute slip, kinking of the retinacular vessels (arrow) may occur leading to ischemia of the femoral epiphysis. In a chronic SCFE, callus formation has built reactively in particular on the posterior aspect of the metaphysis. In the acute-on-chronic situation, kinking may occur again (arrow). In-situ pinning of an acute or chronic slip usually preserves the femoral head blood supply. Closed reduction maneuvers stretch the retinaculum over the posterior callus leading to an increased risk of avascular necrosis. With the modified Dunn-procedure, the greater trochanteric massif is reduced and a soft tissue flap is developed containing the retinacular vessels. With additional shortening, the epiphysis can be reduced safely without tension to the retinaculum.

In 1991, Carney et al presented their large milestone data from Iowa on various treatments for SCFE.[5] They concluded that pinning *in situ* has the lowest risk of AVN, which eventually became the treatment of choice even for severe SCFEs. However, there is increasing evidence that the remaining deformities may imply a substantially higher risk of functional hip problems due to femoroacetabular cam-type impingement in the mid- and long-term with premature hip osteoarthritis.[6,7]

The profound studies on the vascular blood supply to the femoral head at our institution in the past 20 years have led to the development of a surgical dislocation of the femoral head with an almost negligible risk of AVN given a correct surgical technique.[8-10] As an extension of this approach, the retinacular soft tissue flap can reproducibly be developed.[11] This allows full surgical access to the femoral neck and the epiphysis with visual control of the integrity of the retinacular vessels to the femoral epiphysis. Compared with a standard surgical hip dislocation, the dissection is even closer to the afferent vulnerable blood supply to the femoral epiphysis, which puts the retinacular vessels to a somewhat higher risk of iatrogenic injury. Finally, the technique of a subcapital reorientation through a surgical dislocation of the hip with development of a retinacular soft-tissue flap has been developed.[12,13] In this article, we present the indications, the surgical technique, the currently available outcomes from the literature and a self-critical analysis of these results.

Indications

Basically, the modified Dunn procedure can be performed for any type of SCFE. At our institution, it is indicated for every moderate and severe (acute or chronic) SCFE, which covers more than 80% to 90% of our procedures. Mild slips with a Southwick angle of less than 15° are typically treated with in-situ pinning and concomitant arthroscopic or open osteochondroplasty. Here, the slight remaining malorientation of the femoral head cartilage and the mismatch between the acetabular fossa and the fovea of the femoral head seems to be acceptable.

It is crucial to recognise the maximum amount of slippage. This can typically not be seen on the conventional pre-operative radiographs. We therefore perform routinely pre-operative magnetic resonance imaging with acquisition of radial sequences.

Surgical technique

The patient is positioned in the lateral decubitus position with the operated leg positioned on a tunnel pillow (Fig. 2). The entire leg is prepped and draped in sterile fashion. A sterile bag is fixed on the opposite side of the operating table to allow the later dislocation of the hip joint in the figure of four position. A straight lateral incision centered over the greater trochanter is used. The fascia lata is incised along the anterior border of the gluteus maximus muscle and the Gibson interval between the gluteus medius and maximus muscles is developed

(Fig. 3). Perforating epifascial vessels originating from the inferior gluteal artery can be used as landmarks to find the anterior border of the gluteus maximus muscle. The trochanteric bursa is incised and the piriformis and gluteus minimus muscles are identified by retracting the gluteus medius anteriorly. Care must be taken to avoid an iatrogenic injury to the anastomosis of the inferior gluteal artery, which runs at the inferior border of the piriformis muscle. This important and relatively constant anastomosis to the deep branch of the medial circumflex artery can potentially guarantee the blood supply to the femoral head in case of damage of the deep branch.

A straight digastric trochanteric osteotomy is performed leaving the most posterior fibers (approximately 2 mm to 3 mm) of the gluteus medius tendon intact. This ensures that the osteotomy is not too medial potentially endangering the deep branch of the medial femoral circumflex artery. Using this technique most fibers of the piriformis tendon remain attached to the stable portion of the greater trochanter. The capsule is then exposed between the piriformis and gluteus minimus muscles by mobilisation of the trochanteric fragment together with the vastus, gluteus minimus and medius muscles ventrally (Fig. 3).
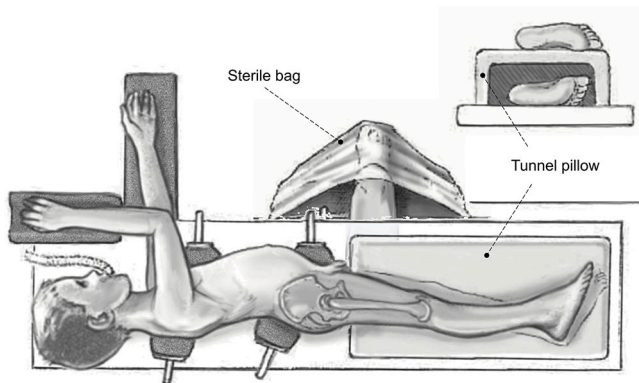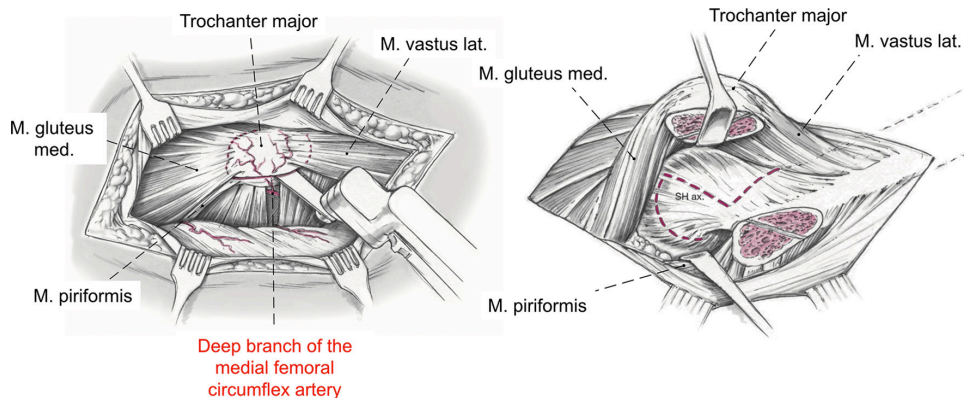
A z-shaped capsulotomy is performed, which allows a direct visualisation of the epiphyseal slip including the prominent metaphysis. In case of an unstable slippage, the femoral epiphysis is temporarily pinned with 2 mm-Kirschner wires (Fig. 4). The viability of the femoral epiphysis is ensured by drilling of the femoral head. In most cases, the epiphysis is bleeding since the posterior slippage basically relaxes the retinacular vessels. However, in severe slips, there is a potential that the retinacular vessels may be kinked leading to a relevant temporary ischemia of the epiphysis.

After cutting the capitis femoris ligament, the femoral head is then dislocated by placing the lower leg in the opposite sterile bag in flexion and external rotation. This allows a full inspection of the corresponding damage to the acetabulum (Fig. 4). Interestingly, there is already considerable damage even in acute slips indicating that there has been some previous ongoing pathology. The chondrolabral damage is often severe independent from the degree of slippage. In mild cases, the asphericity can even enter deeper into the socket than in severe slips.

After relocation of the femoral head, the retinacular soft tissue flap is developed (Fig. 5). This flap contains the deep branch of the medial femoral circumflex artery, the periosteum, the piriformis muscle, part of the posterior capsule, and the short external rotators. The flap is developed by stepwise resection of the most posterior portion of the greater trochanter. The reduction of the greater trochanter starts at the level of the trochanteric apophysis which indicates the base of the femoral neck. The periosteum of the femoral neck is incised along its axis, and the retinacular flap is then carefully mobilised proximally with the periosteal elevator. Distally, the flap should be extended to the level of the lesser trochanter, which significantly reduces the tension from the retinacular vessels (Fig. 6). Anteriorly, the typically partially torn periosteum is peeled off the bone with a periosteal elevator with the head in dislocated position.

The femoral head is then stepwise mobilised using chisels starting from anterior (Fig. 7). This gradual

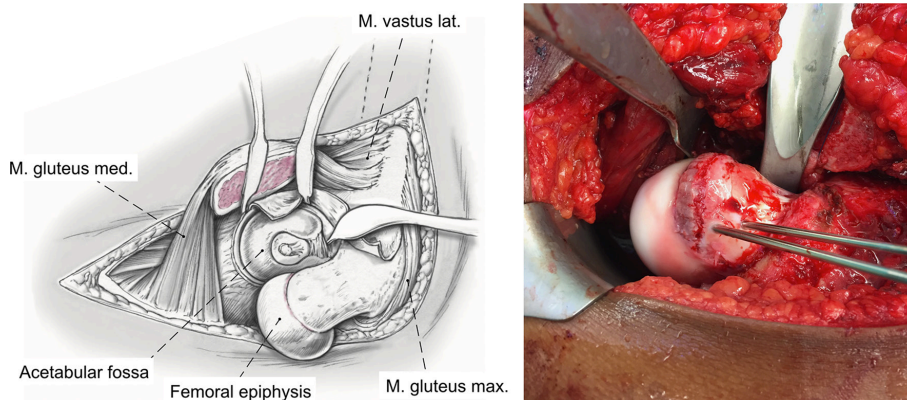**Fig. 2** Patient positioning. Adapted with permission from Leunig et al.[13]

Fig. 3 Greater trochanteric osteotomy and capsulotomy. Adapted with permission from Leunig et al.[13]

Fig. 4 Dislocation of the femoral head after temporary *in situ* pinning of the displaced epiphysis. Adapted with permission from Leunig et al.[13]
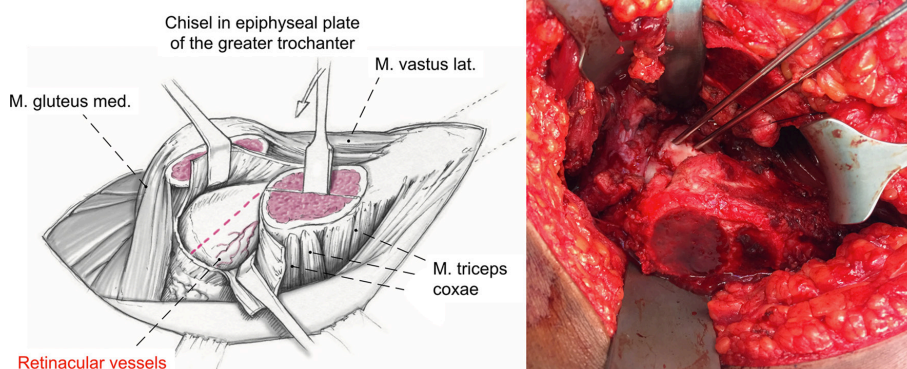

Fig. 5 Periosteal incision and development of the retinacular soft-tissue flap. Adapted with permission from Leunig et al.[13]
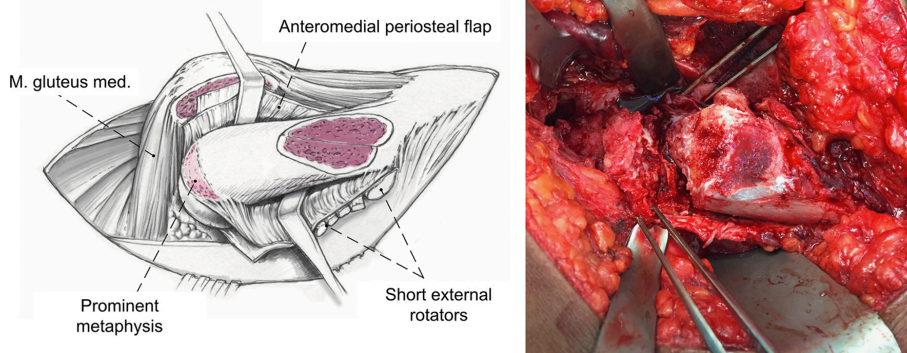

Fig. 6 Final appearance after complete development of the retinacular soft-tissue flap. Adapted with permission from Leunig et al.[13]

separation of the femoral epiphysis from the metaphysis is facilitated with external rotation. Eventually, the epiphysis becomes completely mobile but still attached to the posteroinferior retinacular soft tissue flap. The metaphyseal stump can be best exposed when the epiphysis is relocated in the acetabular socket. The callus formation of the metaphysis is basically always present except in traumatic SCFE and must be resected until a spherical surface of the neck becomes apparent. Further shortening of the neck may be necessary in case of difficulties with the reduction of the epiphysis to prevent tension to the retinacular vessels (Fig. 8).

The epiphyseal scar of the head is then cleaned from growth plate tissue with a curette or a high-speed burr (Fig. 9). Under visual control of the retinaculum, the epiphysis is then reduced manually on the metaphyseal
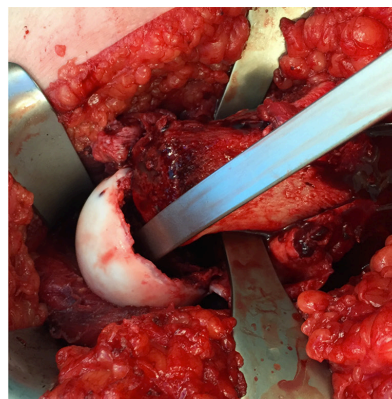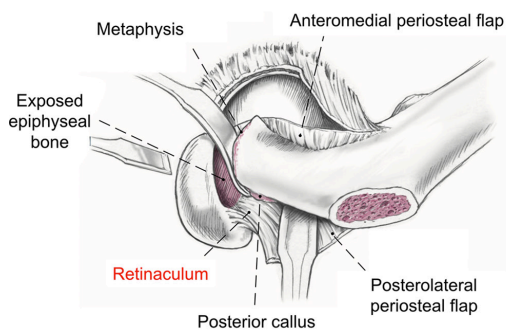
Fig. 7 Mobilisation of the epiphysis from the metaphysis. Adapted with permission from Leunig et al.[13]
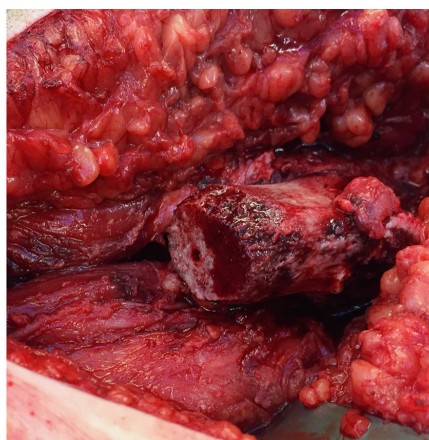

Fig. 8 The metaphyseal stump with the prominent reactive callus formation can be inspected with the epiphysis relocated in the socket (left). The metaphysis is then cleaned from any excessive callus bone.
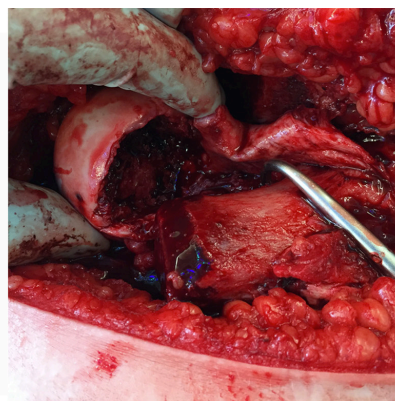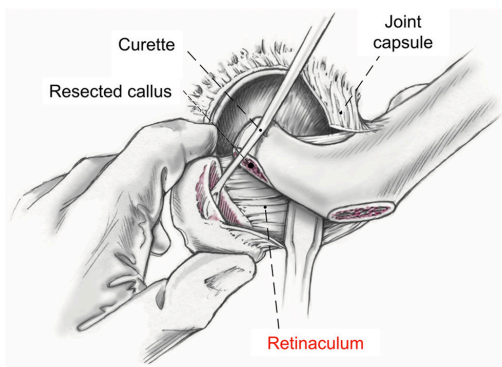

Fig. 9 Curettage of the epiphyseal growth plate. Adapted with permission from Leunig et al.[13]

stump. A 3.0 mm fully threaded Kirschner-wire is placed anterograde starting at the fovea of the femoral head (Fig. 10). One or two more Kirschner-wires are then placed divergently from retrograde in the epiphysis. The correct alignment of the epiphysis is checked by fluoroscope. Epiphyseal perfusion after the capital realignment is checked routinely using a 2 mm-drill hole with observation of subsequent bleeding.

The anterior periosteum and the posterior retinacular flap are then reattached loosely with tension-free sutures. Similarly, the capsule is closed without tension. The greater trochanter is readapted with two

3.5 mm cortical screws optionally with advancement, if needed.

Post-operative care includes the use of a motorised continuous passive motion device during the hospital stay. Partial weight-bearing is needed for eight weeks. After radiographic evidence of consolidation, stepwise transition to full weight-bearing is permitted with normal use of the hip after three months.

Results from the inventor's institution

We have presented the mean 5 and 10-year follow-up of the first 30 hips in 30 patients undergoing the modified Dunn procedure at our institution starting in 1998.[14,15] In this series, there were no cases of avascular necrosis (Fig. 11). The epiphyseal anatomy could be restored with residual slip angles ranging from 4° to 8°. Considerable chondrolabral damage of the acetabulum was observed consistently, regardless of the stability of the slip.[16] These promising results could be reproduced by the Bostonian group.[15] Although there were initial cases of hardware fail-

ure using screws instead of threaded Kirschner-wires, the functional long term outcome of the patients improved significantly.[14] Over the years, 14% of the patients required a secondary procedure to address bone spurs at the femoral head-neck junction and/or the acetabulum that had developed over time leading to a secondary femoroacetabular impingement. Overall, the cumulative ten year survival rate was 93%, which was defined as no progression of OA, no conversion to THA and no poor clinical outcome.[14]

In a second series from our institution including 23 patients between 2004 and 2007, we found one case of osteonecrosis.[17] In this patient with symptoms for more than three weeks, no perfusion of the femoral head was evident after drilling although the retinacular vessels appeared to be macroscopically intact. Unfortunately, unlike in another published case,[18] there was no evidence of reperfusion in a bone scan two weeks post-operatively. Eventually, the patient developed avascular necrosis of the femoral head and required arthrodesis. Based on these two publications, the overall incidence of AVN in our institution is 2%.
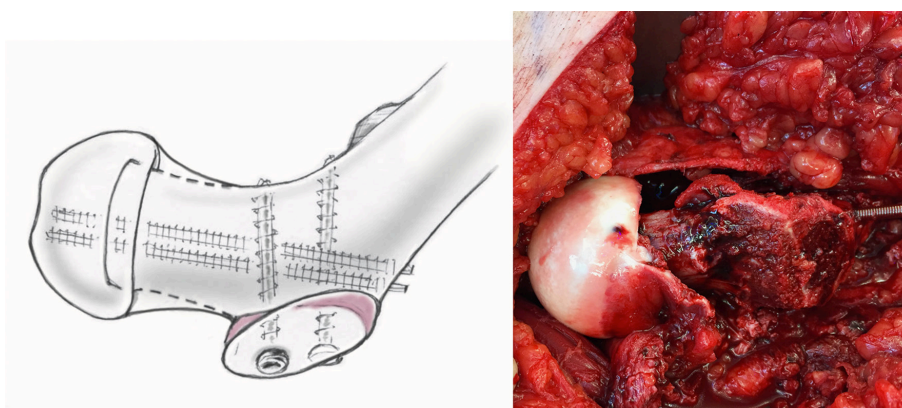

Fig. 10 Fixation of the epiphysis with two to three 3.0 mm fully threaded Kirschner wires. Adapted with permission from Leunig et al.[13]
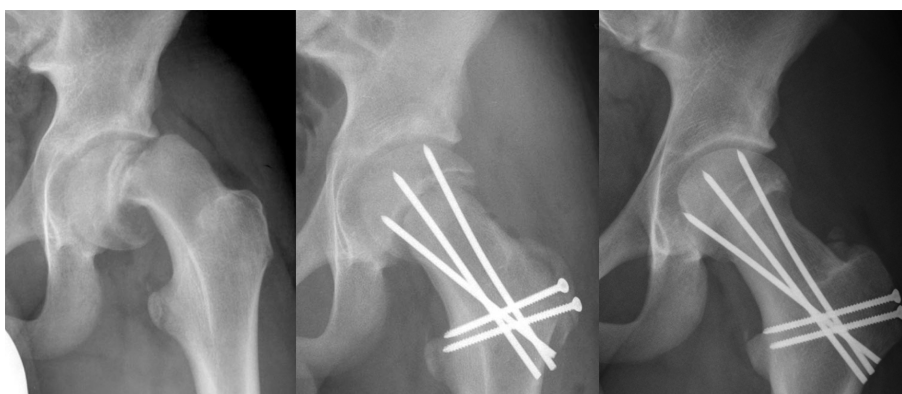

Fig. 11 Example of a 14-year-old male patient with an acute-on-chronic SCFE treated with a modified Dunn procedure using a surgical hip dislocation approach with development of a retinacular soft tissue flap: pre-operatively (left), post-operatively (mid), and at four years follow up.

Table 1. Results of the modified Dunn procedure.

Author (year)	Hips (patients)	Age (years)	Type of SCFE	Slip angle (°)	Followup time (years)	OA progression	Subsequent surgeries THA	Clinical results	AVN Rate
Ziebarth et al. (2009)[15]	I: 30 (30) II: 10 (10)	10–16	Moderate to severe	57 (34–69)	I: 5 (3–8) II: 2 (1–4)		Screw breakage in 3 hips, surgical hip dislocation with offset correction in one hip	A: MdA 17.8, contralateral 17.7, HHS 99.6, flexion 104° (80-120), flexion IR° 29 (5-45), flexion ER 43° (20-60)	None
Slongo et al. (2010)[17]	23 (23)	11 (7–17)	All types	47 (10-80)	2.4 (2-5)	2 hips	Revision of a Kirschner wire in 1 patient	Mean HHS 99	4%
Huber et al. (2011)[23]	30 (28)	12 (9–17)	All types	45 (19–77)	4 (1–9)	Mean slip angle at followup of 5°(-18-25)	4 (13%) revision surgeries	HHS 98/100, WOMAC 6 points for pain,10 for stiffness and 6 for function	3%
Sankar et al. (2013)[20]	27 (27)	13 (10–16)	Unstable	-	2 (1–4)	Mean slip angle at followup 6° (2-11)	4 (15%) revision surgeries due to broken implants; one (4%) THA due to AVN, one core decompression for AVN and one surgical hip dislocation and osteoplasty for residual deformity due to AVN	Patients without AVN had better hip flexion, lower pain score, higher level of satisfaction, and superior functional outcome	26%
Madan et al. (2013)[24]	28 (28)	13 (10–20)	61% unstable	59 ± 12 (40–88)	3 (2–7)	Mean slip angle at followup was 7.5°; 4 hips with AVN had Tönnis 0, 1, 2, 3; remaining hips had Tönnis 0	Additional surgery: 4x pinning contralateral hip, 3x hinged distractor for AVN, 1x pelvic support osteotomy, 1x debridement labral tear, 1x contralateral epiphysiodesis	Mean mHHS was 89 points (88-100), NAHS score 91 points, hip ROM at final follow-up was nearly normal with significant improvements in internal rotation, flexion and abduction.	14%
Upasani et al (2014)[25]	43 (43)	13 (11–16)	Moderate and severe, 86% slip angle >50°	>30 86%	3 (1–8)	7 (16%) patients were initially treated with in situ fixation and revised with the modified Dunn procedure	4 (9%) patients underwent revision surgery for femoral neck non-union; 2 (5%) patients had postoperative hip dislocations; 7/10 patients with AVN had revision surgery: 4x (9%) offset correction, 3x (7%) intertrochanteric osteotomy	---	23% had AVN, 5% had OA and AVN
Souder et al. (2014)[26]	I:71 II:17	12 ± 2 (9–17)	84% stable		I: 3 2 II: 1 ± 1		No clinical results reported	---	I: 43% in unstable slips II: 20% in stable slips, 29% in unstable slips
Novais et al. (2015)[19]	I: 15 II: 15	I: 14 (12–17) II: 13 (10–16)	Severe, stable	I: >60 II: >60	2 (1–6)		One revision for implant failure, one THA for penetrating nail	Heyman and Herndon better for Dunn than pinning	7% Dunn, 7% in situ pinning
Persinger et al. (2016)[27]	31 (30)	12 (9–15)	Unstable		2 (0–7)	Mean postoperative slip angle was 2.5° (-9-19); alpha angle was 47° (34-64); greater trochanter height was 3.5mm below the femoral head center	3/30 (10%) patients had heterotopic ossification without therapy; 2/30 (6%) patients had hardware removal; 1/30 (3%) patient had hardware failure, 3/30 (10%) patients had contralateral in situ pinning	---	6%
Elmarghani et al. (2017)[28]	32 (30)	14 (10-18)	Stable	52 ± 14	1.2	None	One revision for deep infection, no implant failures	Mean Harris Hip Score 96.16 ± 9.7	9.4%

mHHS, (modified) Harris Hip Score; AVN, avascular necrosis

Fig. 12 Example of a 12 year old boy with an unstable left SCFE treated with a modified Dunn procedure (with permission from Sankar et al)[20] pre-operatively (left), post-operatively (mid) and after hardware removal (right) revealing evidence of avascular osteonecrosis. Adapted with the permission of Sankar et al.[20]

Results from other institutions

Given the very promising results from our institution, the modified Dunn procedure has been used in several other centers for moderate and severe SCFEs (Table 1). In a comparative study in severe stable SCFEs, the modified Dunn procedure was found to have a better radiographic correction, a better clinical outcome and a lower reoperation rate compared to in situ pinning.[19]

Analogously to the historical experience with Dunn's original technique, the results from the inventor's institution could only be partially reproduced. The reported rates of AVN varied between 3% and 24% (Table 1, Fig. 12). However, when analysing these results critically, there might be several reasons for this. In particular, the technique was mostly used in acutesevere cases with an inherently higher risk of avascular necrosis in the natural course of the disease. Another limitation might be the relatively high number of surgeons involved compared to our setup resulting in less routine with this demanding surgical technique. The proposed minimum number of ten surgical hip dislocations[20] per year does not seem to be the appropriate number to justify a modified Dunn procedure in our experience. In addition, the exact amount of the individual resection of the callus formation at the posterior level of the femoral neck is crucial. Finding the balance between a too short femoral neck (resulting in instability)[21] and an appropriate neck length to ensure a tension-free reduction of the femoral epiphysis is hard and requires years of surgical experience.[22]

The modified Dunn procedure using the retinacular soft-tissue flap offers the opportunity to anatomically reduce a displaced femoral epiphysis while visually controlling the retinacular perfusion of the femoral head. In experienced hands using the correct meticulous surgical technique, the results are favorable regarding the rates of AVN, the functional outcome and the development of radiographic osteoarthritis – even in acute and severe cases. Avascular necrosis can be observed if there is no evidence of intra-operative femoral head perfusion before and after relocation of the epiphysis.

OA LICENCE TEXT

REFERENCES

1. **Hall JE.** The results of treatment of slipped femoral epiphysis. *J Bone Joint Surg [Br]* 1957;39-B:659-673.

2. **Hiertonn T.** Wedge osteotomy in advanced femoral epiphysiolysis. *Acta Orthop Scand* 1955;25:44-62.

3. **Dunn DM.** The treatment of adolescent slipping of the upper femoral epiphysis. *J Bone Joint Surg [Br]* 1964;46-B:621-629.

4. **Dunn DM, Angel JC.** Replacement of the femoral head by open operation in severe adolescent slipping of the upper femoral epiphysis. *J Bone Joint Surg [Br]* 1978;60-B:394-403.

5. **Carney BT, Weinstein SL, Noble J.** Long-term follow-up of slipped capital femoral epiphysis. *J Bone Joint Surg [Am]* 1991;73-A:667-674.

6. **Fraitzl CR, Käfer W, Nelitz M, Reichel H.** Radiological evidence of femoroacetabular impingement in mild slipped capital femoral epiphysis: a mean follow-up of 14.4 years after pinning in situ. *J Bone Joint Surg [Br]* 2007;89-B:1592-1596.

7. **Zilkens C, Bittersohl B, Jäger M, et al.** Significance of clinical and radiographic findings in young adults after slipped capital femoral epiphysis. *Int Orthop* 2011;35:1295-1301.

8. **Ganz R, Gill TJ, Gautier E, et al.** Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg [Br]* 2001;83-B:1119-1124.

9. **Gautier E, Ganz K, Krügel N, Gill T, Ganz R.** Anatomy of the medial femoral circumflex artery and its surgical implications. *J Bone Joint Surg [Br]* 2000; 82-B:679-683.

10. **Kalhor M, Horowitz K, Gharehdaghi J, Beck M, Ganz R.** Anatomic variations in femoral head circulation. *Hip Int* 2012;22:307-312.

11. **Ganz R, Huff TW, Leunig M.** Extended retinacular soft-tissue flap for intra-articular hip surgery: surgical technique, indications, and results of application. *Instr Course Lect* 2009;58:241-255.

12. **Leunig M, Slongo T, Ganz R.** Subcapital realignment in slipped capital femoral epiphysis: surgical hip dislocation and trimming of the stable trochanter to protect the perfusion of the epiphysis. *Instr Course Lect* 2008;57:499-507.

13. **Leunig M, Slongo T, Kleinschmidt M, Ganz R.** Subcapital correction osteotomy in slipped capital femoral epiphysis by means of surgical hip dislocation. *Oper Orthop Traumatol* 2007;19:389-410.(In German)

14. **Ziebarth K, Milosevic M, Lerch TD, et al.** High Survivorship and Little Osteoarthritis at 10-year Followup in SCFE Patients Treated With a Modified Dunn Procedure. *Clin Orthop Relat Res* 2017;475:1212-1228.

15. **Ziebarth K, Zilkens C, Spencer S, et al.** Capital realignment for moderate and severe SCFE using a modified Dunn procedure. *Clin Orthop Relat Res* 2009;467:704-716.

16. **Ziebarth K, Leunig M, Slongo T, Kim YJ, Ganz R.** Slipped capital femoral epiphysis: relevant pathophysiological findings with open surgery. *Clin Orthop Relat Res* 2013;471:2156-2162.

17. **Slongo T, Kakaty D, Krause F, Ziebarth K.** Treatment of slipped capital femoral epiphysis with a modified Dunn procedure. *J Bone Joint Surg [Am]* 2010;92-A:2898-2908.

18. **Schoeniger R, Kain MS, Ziebarth K, Ganz R.** Epiphyseal reperfusion after subcapital realignment of an unstable SCFE. *Hip Int* 2010;20:273-279.

19. **Novais EN, Hill MK, Carry PM, Heare TC, Sink EL.** Modified Dunn Procedure is Superior to In Situ Pinning for Short-term Clinical and Radiographic Improvement in Severe Stable SCFE. *Clin Orthop Relat Res* 2015;473:2108-2117.

20. **Sankar WN, Vanderhave KL, Matheney T, Herrera-Soto JA, Karlen JW.** The modified Dunn procedure for unstable slipped capital femoral epiphysis: a multicenter perspective. *J Bone Joint Surg [Am]* 2013;95:585-591.

21. **Upasani VV, Birke O, Klingele KE, Millis MB.** International SCFE Study Group. Iatrogenic Hip Instability Is a Devastating Complication After the Modified Dunn Procedure for Severe Slipped Capital Femoral Epiphysis. *Clin Orthop Relat Res* 2017;475:1229-1235.

22. **Aprato A, Leunig M, Massé A, Slongo T, Ganz R.** Instability of the hip after anatomical re-alignment in patients with a slipped capital femoral epiphysis. *Bone Joint J* 2017;99-B:16-21.

23. **Huber H, Dora C, Ramseier LE, Buck F, Dierauer S.** Adolescent slipped capital femoral epiphysis treated by a modified Dunn osteotomy with surgical hip dislocation. *J Bone Joint Surg [Br]* 2011;93-B:833-838.

24. **Madan SS, Cooper AP, Davies AG, Fernandes JA.** The treatment of severe slipped capital femoral epiphysis via the Ganz surgical dislocation and anatomical reduction: a prospective study. *Bone Joint J* 2013;95-B:424-429.

25. **Upasani VV, Matheney TH, Spencer SA, et al.** Complications after modified Dunn osteotomy for the treatment of adolescent slipped capital femoral epiphysis. *J Pediatr Orthop* 2014;34:661-667.

26. **Souder CD, Bomar JD, Wenger DR.** The role of capital realignment versus in situ stabilization for the treatment of slipped capital femoral epiphysis. *J Pediatr Orthop* 2014;34:791-798.

27. **Persinger F, Davis RL II, Samora WP, Klingele KE.** Treatment of Unstable Slipped Capital Epiphysis Via the Modified Dunn Procedure. *J Pediatr Orthop* 2016. [Epub ahead of print]

28. **Elmarghany M, Abd El-Ghaffar TM, Seddik M, et al.** Surgical hip dislocation in treatment of slipped capital femoral epiphysis. *SICOT J.* 2017;3:10.