Total hip replacement in congenital high hip dislocation following iliofemoral monotube distraction

Johannes Holinka · Martin Pfeiffer ·
Jochen G. Hofstaetter · Richard Lass · Rainer I. Kotz ·
Alexander Giurea

Received: 1 March 2010 / Accepted: 8 March 2010 / Published online: 29 March 2010
© Springer-Verlag 2010

Abstract The aim of this study was to prospectively evaluate our single-centre one- and five-year results of anatomically correct cementless total hip arthroplasty in unilateral and bilateral Crowe type IV high hip dislocations in ten hips following iliofemoral monotube soft tissue distraction. Six consecutive patients (five females and one male) with unilateral and two female patients with bilateral high hip dislocation with an average age of 46 years and height of dislocation up to 110 mm were treated in our institution. Limb lengthening was achieved up to 100 mm. The mean leg-length-discrepancy was −4 mm postoperatively. Harris hip score increased significantly at one year ($p < 0.001$) and significantly further ($p < 0.05$) at five years postoperative. WOMAC, VAS pain scale as well as gait and pain-free walking distance also improved significantly at follow-up. Two pin infections and one temporary peroneal nerve palsy occurred during monotube extension. Three cup protrusions that required revision surgery were observed in two patients. This study shows that iliofemoral distraction prior to total hip replacement achieves leg length equality and improved gluteal function and therefore gait in patients with Crowe type IV hip dislocation.

Introduction

Total hip arthroplasty (THA) in patients with severe dysplasia of the hip is a technically challenging procedure.

In particular the neglected Crowe type IV congenital hip dislocation (CDH) or high hip dislocation of Hartofilakidis's classification [1] present many conceptual and technical challenges due to the disturbed anatomy of the proximal femur and acetabulum. A narrow anteverted intramedullary canal of the proximal femur, a deficient bone stock of the acetabulum, soft tissue contractures and muscular insufficiency and shortened neurovascular structures are common findings in these patients [2].

To perform THA in adult patients with high hip dislocation, various surgical techniques have been described in the literature such as femoral shortening, through either a midtrochanteric or, more often, a subtrochanteric resection osteotomy with and without trochanteric re-fixation [2–13]. However, these procedures generally lead to a significant leg-length discrepancy as well as muscle weakness [2, 6–13]. The only reports on the implantation of the cup in the true acetabulum without shortening of the femur after iliofemoral distraction in patients with high hip dislocation were published by Lai et al. [14, 15]. In 1996 he was the first to describe the use of a Wagner's distraction apparatus between the ilium and the distal femur in patients with unilateral, untreated high CDH before THA [15].

Before distraction, he performed a subcutaneous adductor tenotomy and resected the femoral head and released the capsule and soft tissues at time of total hip replacement (THR) [14, 15]. In our department, we used a modified procedure with initial femoral head resection and soft tissue release prior to distraction. The purpose of our study was to prospectively evaluate the five-year results of this modified two-stage procedure with anatomically correct total hip replacement in unilateral and bilateral Crowe type IV high hip dislocations without a shortening femoral osteotomy, using a transgluteal approach following stepwise soft tissue lengthening with an external monotube extension system (Fig. 3c).

J. Holinka (✉) · M. Pfeiffer · J. G. Hofstaetter · R. Lass ·
R. I. Kotz · A. Giurea
Department of Orthopaedic Surgery, Vienna General Hospital,
Medical University of Vienna,
Waehringer Guertel 18–20,
1090 Vienna, Austria
e-mail: johannes.holinka@meduniwien.ac.at

Material and methods

Between 2002 and 2004, six consecutive patients (five females and one male) with unilateral and two female patients with bilateral high Crowe type IV CDH (Fig. 1a) were treated with iliofemoral distraction with a monotube device (Figs. 1b and 3c) before THR. The goal was to achieve leg-length equality as well as cup positioning in the true acetabulum. The study was approved by the institutional review board.

The mean age at the time of surgery was 46 years (range, 27–65 years). At the time of surgery, the mean height was 158 cm (range, 150–182 cm) and the mean weight was 71 kg (63–78 kg) resulting in an average body mass index of 29 (BMI range, 22–33). Four of the six patients with unilateral high CDH had involvement of the right hip and two had involvement of the left.

Preoperatively and at each follow-up (one and five years post-op) Harris hip score (HHS), WOMAC score [16, 17], pain intensity using the visual analogue scale (VAS) as well as the walking distance were determined. The validated German version of the WOMAC [17] uses a numeric graduate scale (1–10 points) instead of the visual analogue scale (1–100 mm) [18]. The global index of the German scale can be multiplied by the factor 10 to match the value of the international WOMAC global index [17]. Moreover, a clinical examination with special attention to the function of the gluteus medius muscle and range of motion was performed. At the five-year follow-up patients were asked if they would undergo this two-step surgical procedure again. All patients also underwent a detailed clinical neurological examination focussing on sciatic nerve function. Electromyography and nerve conduction velocity studies were not done routinely.

Standing radiographs of the hip were made and leg length discrepancy was measured with digital radiological Impax ES software (AGFA). The apex of the lesser trochanter and the caudal bone marking of the tear drop figure were used as anatomical landmarks for length measurements. Anteroposterior and axial radiographs of the hip were made to assess the severity of femoral anteversion, the position of the femoral head in relation to acetabulum and the size of the medullary canal. Conventional and special undersized templates were used to estimate the size of the prosthetic implants. The acetabulum was evaluated for suitability for augmentation with structural bone graft from the femur head and/or medialisation of the cup. The clinical and the radiographic examinations at follow-up were done by a surgeon, who had not been involved in the index surgery.

Surgical procedure

All surgical procedures were carried out by the senior author. A transgluteal lateral approach was used in all

Fig. 1 Radiographs of a 42-year-old female patient with bilateral high hip dislocation. **a** Preoperatively. **b** Following femoral head resection, soft tissue release and during distraction using a unilateral monotube device. **c** Radiographs following bilateral total hip replacement with cup placement in the true acetabulum after sequential bilateral monotube extension at five years postoperative (right hip; five years plus eight months on the left hip)

patients. The femoral head was removed and the joint capsule was excised as completely as possible. An adductor tenotomy and a tenotomy of the iliopsoas insertion at the lesser trochanter was performed. Depending on bone quality three to four Schantz screws were inserted percutaneously between both cortices of the iliac crest in parallel fashion. Two to three Schantz screws were also inserted into the proximal femur parallel to the screws in the iliac crest. An external monotube extension system (Stryker-Howmedica, USA) (Figs. 1b and 3c) was assembled for distraction. Initial distraction of 1 cm was made on the first day. Each day distraction of 2–5 mm, depending on the pain tolerance of each patient, was achieved. Vital signs and neurovascular functions of the limb were closely monitored during the distraction period. Pin-tract care was instituted to prevent infection. Radiographic evaluation of the distraction was performed weekly. Patients were confined to bed during this period. When the lesser trochanter passed the teardrop, a cementless total hip arthroplasty was performed using a tapered, rectangular stem made of titanium-aluminium-niobium alloy (Zweymüller Alloclassic; Zimmer, Winterthur, Switzerland and Warsaw, IN, USA) and a conical screw cup (CSF; Zimmer [previously Sulzer]) [19, 20] (Fig. 1c). The aim of reconstruction was to place the cup into the true acetabulum. After reaming the acetabulum, a cementless conical screw-cup was implanted. In three cases bone grafting of the acetabular roof with autologous cancellous bone from the femoral head, which had been frozen at -80°C under aseptic conditions, was necessary. To fit the hypoplastic bony stock of the acetabulum and the narrow medullary canal of the femur, the use of undersized components was necessary in most cases. All components were implanted without bone cement. We used six metal-metal bearings and four polyethylene-ceramic bearings, two of them with an elevated liner. In nine hips 28-mm heads were used and in two cases 22-mm heads were used. One hour before each surgical intervention, all patients received prophylactic antibiotic single-shot therapy with 2 g cephazoline; this was maintained three times per day for five days after the second intervention depending on the duration of total hip arthroplasty. Mobilisation was started two to five days after surgical intervention under a physiotherapist's instruction. Our standard mobilisation protocol was non-weight bearing on the operated leg with two crutches for six weeks. Full weight bearing was allowed three months after surgery.

Statistical analysis

Repeated measures ANOVA with Bonferroni's multiple comparison test were used to evaluate statistical significance between the different time points. Nonparametric correlation (Spearman correlation coefficient) was performed between

the rate of distraction and the total length of monotube distraction. All statistical calculations were done using Graph Pad Prism 4.0 (San Diego, CA, USA). A p -value less than 0.05 was considered statistically significant.

Results

The mean high hip dislocation was 63 mm (range, 24–110 mm) preoperatively. The mean length of monotube distraction was 56 mm (range, 19–93 mm) (Fig. 2a, b). Because of pin-infection two monotubes had to be removed after 8 mm and 13 mm of distraction and were changed for trans-tibial Steinmann pin traction. With the Steinmann pin traction another 33 mm of distraction could be achieved in the first and 28 mm in the second patient. The mean period of distraction was 29 days (range, 18–49 days). The entire distraction results showed a mean lengthening of 65 mm (range, 29–100 mm). Through anatomically correct placement of the implants and repositioning of the hip prostheses an additional mean distraction of 12 mm (range, 0–46 mm) could be achieved. At the latest follow-up the mean leg-length discrepancy in digital radiograph measurements was -4 mm (range, 0 to -20 mm). The mean preoperative hip flexion was 100 ± 19.2 degrees with no significant improvement at one year (100 ± 11.8 degrees) and no further significant improvement at five years follow-up (105 ± 12 degrees). The mean preoperative HHS was 49 ± 20.1 points and was significantly improved at one year (76 ± 16.9 ; $p < 0.001$) and further significantly increased to 87 ± 11.7 points ($p < 0.05$) five years postoperatively (Fig. 3a). The mean preoperative WOMAC score was 6 ± 2.5 and was significantly better at one-year follow-up (2 ± 1.8 ; $p < 0.001$) and at five-year follow-up (1 ± 0.8) (Fig. 2b). The preoperative mean pain score was 8 ± 1.5 and was significantly lower at one year (3 ± 2 ; $p < 0.001$) and even lower at five-year follow-up (1 ± 0.9 ; $p < 0.001$) (Fig. 2c). The mean preoperative painless walking distance was 400 m (range, 100–1000 m); at one-year follow-up it was 1200 m (range, 500–2000 m) and it was significantly increased at five-year follow-up to 3300 metres (range, 1000–5000, $p < 0.001$) (Fig. 2d).

All patients showed preoperative gluteal insufficiency with a positive Trendelenburg sign and positive Duchenne limping on the dislocated side. Patients with bilateral high hip dislocation (Fig. 1a) showed positive Duchenne limping on both sides. Five patients at one-year follow-up and seven patients at five-year follow-up had considerably improved gluteal function following of intensive physical training and were Trendelenburg negative on clinical testing. One of the three patients suffering from ongoing muscular insufficiency had an intraoperative fracture of the greater trochanter and the other two patients needed a revision surgery for cup

Fig. 2 **a** Height of hip dislocation (HD) in millimetres and the distance of the achieved distraction using monotube distraction (ME) displayed for each patient. Two patients (marked with *continuous lines*) had pin infections and monotube distraction was discontinued. **b** There was a positive correlation ($r^2=0.77$) between the total monotube distraction and the extension rate per day in our patients. The only patient suffering from a temporary peroneal nerve palsy following total hip replacement (marked with a *black box*) was one of two patients with the highest distraction rate per day as well as greatest total distraction. **c** Postoperative photographs of the assembled monotube distraction system following femoral head resection and soft tissue release

protrusion and had therefore an extended time for physical rehabilitation. In one patient a temporary palsy of the peroneal nerve was observed following THR. Interestingly, this patient was one of two patients with the fastest distraction rate of 3 mm/day and also greatest total monotube distraction of 82 mm (Fig. 3b). Three patients had a pin infection during distraction. In two patients, the monotube distraction had to be discontinued due to an infection with enterococcus faecalis. In these patients, the distraction was

changed to a standard trans-tibial Steinmann-pin traction technique. Two patients suffered a small avulsion fracture of the greater trochanter, which led to a delayed mobilisation. Three patients had a cup protrusion, one of them immediately after implantation, another one four weeks after operation. In both cases revision surgery was necessary and a bigger cup of the Alloclassic system was used. One patient developed cup loosening in the fourth and ninth weeks after implantation. For the first revision we used a spherical

Fig. 3 Preoperative scores, and one- and five-year postoperative results. **a** Harris hip score (HHS). **b** WOMAC score. **c** Pain VAS (mean $\pm$ standard deviation). **d** Pain-free walking distance in metres (mean $\pm$ SD). * $p < 0.05$, ** $p < 0.001$

porous-coated press-fit cup with two stabilising screws, which failed five weeks later. For the second revision after protrusion we implanted a cemented Burch-Schneider cup [21] with several additional screws for stabilisation. One hip joint dislocated 12 months after hip arthroplasty. In this case we changed the short-neck head into a long-neck head and achieved stable conditions.

At the five-year follow-up all patients declared they would undergo this two step surgical procedure again because of the enormous benefit of improved quality of life.

Discussion

In this study we report our prospective five-year results of a modified two-stage procedure with anatomically correct cup placement of a cementless THR in unilateral and bilateral Crowe type IV high hip dislocations without shortening femoral osteotomy. A transgluteal approach following stepwise soft tissue lengthening with an external monotube distraction system was used. The technique of preoperative iliofemoral distraction that was first described by Lai et al. [15] allows hip reduction without sacrificing femoral length. Our technique of soft tissue distraction varies from that of Lai [14, 15]. Lai et al. [14, 15] only performed a subcutaneous adductor tenotomy prior to

distraction and resected the femoral head and the capsule for soft tissue release at the time of THR. The rationale behind changing this approach was that we postulated that the distraction process of up to 10 cm in length would be easier to achieve if a thorough capsular resection and soft tissue release were performed prior to the monotube extension. Using our approach it is also possible to remove bone overgrowth obstructing the true acetabulum to achieve free and unrestricted limb lengthening without femoral head impingement. Moreover, Lai et al. [14, 15] used a Wagners apparatus which is large and fixed to the distal femur, whereas our smaller monotube device is fixed to the proximal femur. In their recent paper, Lai et al. reported on 56 patients with unilateral Crowe type IV high hip dislocation with good and excellent results and an average HHS score of 90.2 points at an average follow-up of 147.2 months. In 12 patients they used a lateral Hardinge approach to the hip, and a direct lateral approach through a trochanteric osteotomy was used in 43 patients who had trochanteric overgrowth. A direct lateral approach with a proximal femoral osteotomy was used in one patient [14].

In our patients a lateral transgluteal approach was used and equal leg-length as well as comparable HSS at one and five years was achieved. It is important to note that the patients had a significantly better clinical outcome at five years when compared to the one-year follow-up.

In our patient series, the rate of distraction was mainly determined by the patients' pain tolerance; however, the patients with the greatest preoperative height of dislocation reached the greatest rate of distraction per day. Nerves seem to be quite elastic [22], but it may be noteworthy that the only patient that had a temporary nerve palsy in our results was one of two patients with the greatest distraction rate, with 3 mm per day and a total distraction of 82 mm, which further indicates that the risk of nerve palsy correlates with the length of soft tissue distraction. Up to the maximum distraction length of 55 mm, Lai et al. did not observe any nerve palsy [14].

As a consequence of an increased anteversion of the proximal femur, the dysplastic acetabulum often presents deficient bone stock and modified anteroposterior dimensions, which could favour an increased rate of dislocation and acetabular component loosening in THA for dysplastic hips [23, 24]. Lai et al. [14] described nine cup revisions out of 49 patients at a mean follow-up of 147.2 months—four because of polyethylene wear and the other five because of cup loosening. Bicanic et al. [25] stated that the placement of the acetabular cup is of great importance because usually every deviation from the ideal centre of rotation negatively influences endoprosthesis survival, polyethylene wear and hip load.

Numair et al. [12] described a 15% revision rate of the acetabular component in the group of high hip dislocations. In review of these papers [8, 12, 14, 24], cup loosening seems to be a general complication of THR in high hip dislocation regardless of the surgical technique and the techniques of prosthetic implantation whether cemented or cement free. All three cup protrusions we observed were early complications during the first four weeks after implantation. These early cup protrusions may be due to the high soft tissue tension in combination with the poor quality of acetabular bone stock. There was no further cup or stem loosening observed up to the five-year follow-up. The Alloclassic hip prostheses system using a conical screw cup has excellent long-term results with 98% survival of the cement free stem and 85% for the cement free conical screw cup at 15-year follow-up [19].

Because of the anatomical abnormalities of the acetabulum, especially combined with the narrow medullary canal of the femur, the standard-sized prostheses components may not always be compatible. Precise preoperative planning is crucial in these procedures. In three out of ten hips we used special undersized stems.

While Lai et al. [14] reported no pin infection in his patient series, we had three patients with pin infection despite meticulous pin-site care and systemic antibiotic therapy, and in two cases the monotube distraction had to be discontinued. The reason for our high rate of pin infections compared to Lai et al. [14] can be explained by

a shorter period and a lower length of extension in their study population [14]. Another predictive reason for a higher pin infection rate could have been the one-stage hip joint release with femoral head resection together with the monotube device fixation. After this procedure the patients had to stay in bed and were not able to move the hip which prolongs the resorption of the local haematoma, which, in turn, acts as medium for bacterial growth. However, Lai et al. [14] reported that the iliac pins loosened in six patients and had to be removed. In our study group we did not observe aseptic pin loosening.

Because of routine post-natal ultrasound screening of the hip developed by Graf [26], congenital high hip luxation has become a rare occurrence for adults. The small patient sample size is one of the limitations of this study, but shows indirectly that the ultrasound investigation of the neo-natal hip is highly effective. All but one patient in our study were immigrants from countries where the post-natal ultrasound screening method is not performed routinely.

The standard technique used to reduce the hip is femoral shortening through either a midtrochanteric or, more often, a subtrochanteric resection osteotomy [2, 6–13]. The technique of femoral head resection and excision of the joint capsule facilitates the iliofemoral distraction up to 100 mm and allows hip reduction without sacrificing femoral length.

Major complaints from the patients included the limited mobility during monotube distraction combined with restricted personal hygiene for several weeks in addition to the average 35 days spent in hospital. However, all patients said they would undergo this two-step surgical procedure again because of the enormous benefit of improved quality of life.

Conclusion

In summary, our modified surgical procedure according to Lai et al. [14] with immediate femoral head resection and extensive soft tissue release prior to distraction and THR requires careful planning as well as the compliance of the patients. This therapy shows satisfying five-year results in unilateral and bilateral Crowe type IV high hip dislocations. The advantage of this procedure is that equal leg length as well as improved gluteal function due to anatomically correct cup placement can be achieved.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Hartofilakidis G, Stamos K, Ioannidis TT (1988) Low friction arthroplasty for old untreated congenital dislocation of the hip. *J Bone Joint Surg Br* 70:182–186

2. Crowe JF, Mani VJ, Ranawat CS (1979) Total hip replacement in congenital dislocation and dysplasia of the hip. *J Bone Joint Surg Am* 61:15–23
3. Delimar D, Cicak N, Klobucar H, Pecina M, Korzinek K (2002) Acetabular roof reconstruction with pedicled iliac graft. *Int Orthop* 26:344–348. doi:[10.1007/s00264-002-0381-1](https://doi.org/10.1007/s00264-002-0381-1)
4. Pitto RP, Schikora N (2004) Acetabular reconstruction in developmental hip dysplasia using reinforcement ring with a hook. *Int Orthop* 28:202–205. doi:[10.1007/s00264-004-0559-9](https://doi.org/10.1007/s00264-004-0559-9)
5. Papachristou G, Hatzigrigoris P, Panousis K, Plessas S, Sourlas J, Levidiotis C, Chronopoulos E (2006) Total hip arthroplasty for developmental hip dysplasia. *Int Orthop* 30:21–25. doi:[10.1007/s00264-005-0027-1](https://doi.org/10.1007/s00264-005-0027-1)
6. Charnley J, Feagin JA (1973) Low-friction arthroplasty in congenital subluxation of the hip. *Clin Orthop Relat Res*:98–113
7. Dunn HK, Hess WE (1976) Total hip reconstruction in chronically dislocated hips. *J Bone Joint Surg Am* 58:838–845
8. Hartofilakidis G, Georgiades G, Babis GC, Yiannakopoulos CK (2008) Evaluation of two surgical techniques for acetabular reconstruction in total hip replacement for congenital hip disease: results after a minimum ten-year follow-up. *J Bone Joint Surg Br* 90:724–730. doi:[10.1302/0301-620X.90B6.20490](https://doi.org/10.1302/0301-620X.90B6.20490)
9. Hartofilakidis G, Karachalios T (2004) Total hip arthroplasty for congenital hip disease. *J Bone Joint Surg Am* 86-A:242–250
10. Hartofilakidis G, Stamos K, Karachalios T (1998) Treatment of high dislocation of the hip in adults with total hip arthroplasty. Operative technique and long-term clinical results. *J Bone Joint Surg Am* 80:510–517
11. Hartofilakidis G, Stamos K, Karachalios T, Ioannidis TT, Zacharakis N (1996) Congenital hip disease in adults. Classification of acetabular deficiencies and operative treatment with acetabuloplasty combined with total hip arthroplasty. *J Bone Joint Surg Am* 78:683–692
12. Numair J, Joshi AB, Murphy JC, Porter ML, Hardinge K (1997) Total hip arthroplasty for congenital dysplasia or dislocation of the hip. Survivorship analysis and long-term results. *J Bone Joint Surg Am* 79:1352–1360
13. Paavilainen T, Hoikka V, Solonen KA (1990) Cementless total replacement for severely dysplastic or dislocated hips. *J Bone Joint Surg Br* 72:205–211
14. Lai KA, Shen WJ, Huang LW, Chen MY (2005) Cementless total hip arthroplasty and limb-length equalization in patients with unilateral Crowe type-IV hip dislocation. *J Bone Joint Surg Am* 87:339–345. doi:[10.2106/JBJS.D.02097](https://doi.org/10.2106/JBJS.D.02097)
15. Lai KA, Liu J, Liu TK (1996) Use of iliofemoral distraction in reducing high congenital dislocation of the hip before total hip arthroplasty. *J Arthroplasty* 11:588–593
16. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW (1988) Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 15:1833–1840
17. Stucki G, Meier D, Stucki S, Michel BA, Tyndall AG, Dick W, Theiler R (1996) Evaluation of a German version of WOMAC (Western Ontario and McMaster Universities) arthrosis index. *Z Rheumatol* 55:40–49
18. Bellamy N (1995) WOMAC osteoarthritis index: a user's guide. Victoria Hospital, London, Ontario, Canada
19. Grubl A, Chiari C, Giurea A, Gruber M, Kaider A, Marker M, Zehetgruber H, Gottsauner-Wolf F (2006) Cementless total hip arthroplasty with the rectangular titanium Zweymuller stem. A concise follow-up, at a minimum of fifteen years, of a previous report. *J Bone Joint Surg Am* 88:2210–2215. doi:[10.2106/JBJS.E.00810](https://doi.org/10.2106/JBJS.E.00810)
20. Grubl A, Chiari C, Gruber M, Kaider A, Gottsauner-Wolf F (2002) Cementless total hip arthroplasty with a tapered, rectangular titanium stem and a threaded cup: a minimum ten-year follow-up. *J Bone Joint Surg Am* 84-A:425–431
21. Schatzker J, Glynn MK, Ritter D (1984) A preliminary review of the Muller acetabular and Burch-Schneider antiprotusio support rings. *Arch Orthop Trauma Surg* 103:5–12
22. Sunderland S (1968) Nerves and nerve injury, 2nd edn. Churchill Livingstone, New York, pp 62–66
23. Argenson JN, Flecher X, Parratte S, Aubaniac JM (2007) Anatomy of the dysplastic hip and consequences for total hip arthroplasty. *Clin Orthop Relat Res* 465:40–45. doi:[10.1097/BLO.0b013e3181576052](https://doi.org/10.1097/BLO.0b013e3181576052)
24. Iida H, Matsusue Y, Kawanabe K, Okumura H, Yamamuro T, Nakamura T (2000) Cemented total hip arthroplasty with acetabular bone graft for developmental dysplasia. Long-term results and survivorship analysis. *J Bone Joint Surg Br* 82:176–184
25. Bicanic G, Delimar D, Delimar M, Pecina M (2009) Influence of the acetabular cup position on hip load during arthroplasty in hip dysplasia. *Int Orthop* 33:397–402. doi:[10.1007/s00264-008-0683-z](https://doi.org/10.1007/s00264-008-0683-z)
26. Graf R (1980) The diagnosis of congenital hip-joint dislocation by the ultrasonic Comboud treatment. *Arch Orthop Trauma Surg* 97:117–133