Rocco P. Pitto · Nils Schikora

Acetabular reconstruction in developmental hip dysplasia using reinforcement ring with a hook

Received: 17 February 2004 / Accepted: 17 March 2004 / Published online: 30 April 2004
© Springer-Verlag 2004

Abstract We followed prospectively 27 patients with severe acetabular bone-stock deficiencies due to developmental dysplasia of the hip. Mean preoperative patient age was 56 (34–78) years, mean Harris hip score was 31 (16–66) points and pre-operative mean acetabular angle of Sharp was 47° (34°–61°). Operative acetabular reconstruction was performed in 28 hips using reinforcement ring with a hook placed in the true acetabulum and autologous bone grafting. A 2-year clinical and radiological follow-up was available in 27 hips. Mean Harris hip score improved to 91 (70–100) points. There were no clinical or radiological signs of aseptic loosening in 25 hips, and the bone graft was radiologically incorporated in all hips. In 24 hips, a radiostereometric analysis showed low rates of non-progressive translation and rotation in 21 reinforcement rings. Three rings showed progressive translation and/or rotation at the 2-year follow-up and were rated probably loose.

Résumé Nous avons suivi 27 malades avec des déficiences acétabulaires sévères dû à une dysplasie de développement de la hanche. L'âge moyen préopératoire des malades était de 56 ans (34–78), le score moyen de Harris était de 31 points (16–66) et l'angle moyen de Sharp préopératoire était de 47° (34°–61°). La reconstruction acétabulaire a été exécutée dans 28 hanches en utilisant un anneau de renforcement avec crochet, placé dans le paléo-cotyle, avec greffe osseuse autologue. Un suivi clinique et radiologique de 2 années était disponible pour 27 hanches. Le score moyen de Harris a été amélioré à 91 points (70–100). Il n'y avait pas de signe clinique ou radiologique de descellement aseptique dans 25 hanches et la greffe osseuse était incorporée dans toutes les hanches. Dans 24 hanches une analyse radiostéréométrique a montré un faible taux de translation et de rotation, non progressive, de 21 anneaux de renforcement. Trois

anneaux ont montré une translation et/ou une rotation progressive au cours du suivi de 2 années et ont été considérés comme descellés.

Introduction

Total hip replacement (THR) for secondary osteoarthritis in developmental hip dysplasia remains a difficult and challenging procedure. Modern cementing techniques and new design of femoral components have substantially improved the long-term prognosis of stem stability [5, 22, 25]. On the other hand, in severe acetabular deformities with marked bone-stock deficiencies, implant fixation becomes a technical hazard and continues to be considered an unsolved issue [3, 7, 15]. The reinforcement ring (RR) with the hook of Ganz in combination with autologous graft augmentation has been designed to address this issue [8]. A previous in vitro investigation showed stable initial stability of an RR in acetabuli with bone-stock deficiencies simulating severe acetabular dysplasia [17]. Mid-term outcomes reported by the designer group are promising [8]. However, little data has been reported so far from independent authors to confirm the reproducibility of the results [2]. Radiostereanalysis (RSA) is a validated tool for long-term prognosis of implant fixation in THR [1, 9, 12]. Hence, the aim of this study was to investigate the stability of an RR with a hook in developmental hip dysplasia using radiostereometric analysis.

Material and methods

The prospective study was approved by the local ethics committee, and informed consent was obtained from patients one day before the index operation. Twenty-eight consecutive hips (27 patients) with dysplasia were operated on using an RR with hook and autologous bone grafting. The RR (Centre-Pulse, Switzerland) is made of pure titanium with an external grit-blasted porous surface. There were six men and 22 women. Mean patient age at surgery was 56 (range, 34–78) years, and mean pre-operative Harris hip score was 31 (range, 16–66) points. Four patients were rated Charnley class A, and 23

R. P. Pitto (✉) · N. Schikora
Department of Orthopaedic Surgery, Middlemore Hospital,
South Auckland Clinical School, University of Auckland,
Private Bag 93 311 Auckland, New Zealand
e-mail: rpitto@middlemore.co.nz

patients were class B. All hips presented a positive Trendelenburg sign before the index operation. Mean pre-operative Sharp acetabular angle [21] was 47° (range, $34\text{--}61^\circ$). Severity of hip dysplasia was rated according to Crowe [4]; there were nine type I, 13 type II, five type III and one type IV. Sixteen hips had previous surgery (eight Chiari osteotomies, two spherical osteotomies, nine proximal femoral osteotomies).

Surgery was performed under general anaesthesia with the patient in supine position. A direct lateral approach was used in 18 hips; an ilio-femoral approach was used in ten hips with previous acetabular or pelvic surgical procedure. All operations were performed by one surgeon (RPP). Reaming was performed to remove any remaining cartilage from the acetabulum or floor osteophytes. Care was taken to obtain 50% or more of host-bone coverage of the RR. Hence, in some hips, deepening of the acetabular floor was required. Autologous bone was harvested from the femoral head and from the proximal femoral metaphysis. After placement of the ring with the hook around the inferior border of the acetabular floor, the morcellised graft was impacted to the antero-lateral quadrant of the deficient acetabulum using the RR itself, with fixation from 6.5 mm titanium cancellous screws. The number of screws used was determined by the quality of the host bone. Structural autologous grafts were used in combination with morcellised grafts in Crowe III and IV hips to obtain adequate bone-stock restoration. An ultra-high-molecular-weight polyethylene liner (CeraVer, France) was cemented (Palacos-R, Germany) in nine hips. A cup liner with a metal articulating surface (Metasul, Centre-Pulse) was cemented in the remaining hips. The cup was oriented in 45° of inclination and 10° of anteversion. Hips with full polyethylene liner received an alumina femoral head with a diameter of 32 mm and an uncemented femoral component with tapered design (CeraVer). A 28-mm Metasul femoral head and an uncemented femoral component with conical or taper design (Wagner-Conus, CLS-System, Centre-Pulse) was used in the remaining hips. Postoperatively, all patients received deep-vein thrombosis prophylaxis using foot pumps. Partial weight bearing was started at day 2 after surgery and continued until the 8th postoperative week. Clinical and radiographic evaluation was performed using published criteria [10]. Radiolucent lines were rated according to Freeman [6]. RR stability

based on conventional follow-up radiographs was assessed using the method described by Gill [7].

Nine tantalum markers with a diameter of 1 mm were inserted into the periacetabular bone, and nine tantalum markers were inserted into the cup liner before implantation. RSA radiographic examinations were performed post-operatively and at 6 weeks, 3 months, 6 months, 1 year and 2 years after operation. Image processing was performed using a digital radiology system. The images were transferred to the software system using a scanner (Umax, Mirage II). RSA evaluation of the acetabular components was performed by an independent observer (NS) using the dedicated software tool UmRSA 4.1 (BioMedical Innovations, Sweden). Assessment of precision of our RSA equipment performed in a separate study showed satisfactory results [20], comparable to those reported by other research groups [1, 12, 23].

Results

A clinical and radiological follow-up of 24 months was available for 27 hips. One hip required revision surgery because of acute fracture of the cement and loosening of the polyethylene liner 3 months after the index operation. The RR and screws were firmly fixed in the acetabulum, and the autologous graft appeared incorporated with the host bone at the stage of revision. Mean Harris hip score at follow-up was 91 (range, 70–100) points; 25 hips were pain free and had a range of motion of 120° or more. No clinical signs of loosening were present at follow-up in 25 hips. A positive Trendelenburg sign disappeared in 25 hips after the index operation. No post-operative deep-vein thrombosis and dislocation were observed.

RR placement was within 5 mm of the anatomic joint centre in all hips. Mean post-operative hip joint centre distalisation was 13 (range, 3–39) mm; mean medialisa-

Fig. 1 **a** Antero-posterior radiograph of a 29-year-old woman (body mass index 35) shows severe osteoarthritis secondary to developmental hip dysplasia and previous Chiari osteotomy. **b** Two-year follow-up after reconstruction using reinforcement ring with hook and autologous bone grafting. The centre of the hip was restored by placing the hook around the radiological teardrop. The graft healed without signs of resorption. Conventional radiograph shows tantalum markers in the peri-acetabular bone and in the polyethylene liner

Fig. 2 Proximal and horizontal translation of 24 reinforcement rings

tion was 14 (range, 5–42) mm (Fig. 1). Twenty-six RRs were considered stable on conventional radiographs. One RR showed progressive radiolucent lines at the construct's metal-bone interface and broken screws and hook at the latest follow-up. Bone scan of another ring rated stable on conventional radiographs showed possible aseptic loosening. Currently, both patients are symptomatic and are booked for revision surgery. Two rings showed partial non-progressive radiolucent lines along the lateral margin of the metal-bone interface. Osteolytic lesions were not observed within the 2-year follow-up period. All bone grafts healed fully and showed no signs of resorption.

A suitable 2-year RSA follow-up was available for 24 hips. Three asymptomatic hips rated stable on conventional radiographs were excluded because of incomplete RSA records at the latest follow-up. Twenty-one hips showed low rates of non-progressive translation and rotation of the RR (Table 1, Figs. 2, 3). Three hips (12.5%), including the hip with broken screws and hook and the hip with positive bone scan, showed progressive translation and/or rotation at the 2-year follow-up and were rated probably loosened (Table 2). Patterns of displacement of the 24 hips subdivided into four groups according to the Crowe classification for severity of

Fig. 3 Rotation around the longitudinal and sagittal axis of 24 reinforcement rings

dysplasia showed no statistically significant difference ($p \leq 0.05$). Displacement patterns of the RR in hips with or without previous operation were similar.

Discussion

The objective of this study was to assess the in vivo stability of the RR with hook in developmental hip dysplasia using RSA. Patterns of migration were comparable to those reported in the literature using press-fit cups in hips with normal bone stock [12, 23]. Nevertheless, the average magnitude of the overall migration of the RR was noticeably higher, similar to values observed in THR revision settings [16]. Three of 24 hips showed progressive rotation and/or displacement of the RR at the 2-year follow-up mark, a predictive factor for implant fixation failure in the long-term [11, 13]. In addition, one hip required revision surgery following a fall by the patient, resulting in acute failure of fixation at the cement-metal interface of the acetabular construct. The patient was symptom-free and had normal hip-joint function before the accident. This mechanical complication was the only one

Table 1 Migration of 24 reinforcement rings at the 2-year follow-up (mean $\pm$ standard deviation): proximal translation, lateral translation, rotation along the longitudinal (anteversion) and sagittal

Follow-up	Proximal translation (mm)	Lateral translation (mm)	Rotation longitudinal axis (degrees)	Rotation sagittal axis (degrees)
6 weeks	0.07 $\pm$ 0.12	0.14 $\pm$ 0.11	0.29 $\pm$ 0.60	0.01 $\pm$ 0.55
3 months	0.08 $\pm$ 0.28	0.17 $\pm$ 0.18	0.19 $\pm$ 0.71	0.07 $\pm$ 0.65
6 months	0.01 $\pm$ 0.33	0.08 $\pm$ 0.20	0.06 $\pm$ 1.10	0.09 $\pm$ 0.45
1 year	0.30 $\pm$ 0.51	0.30 $\pm$ 0.44	0.12 $\pm$ 1.06	0.46 $\pm$ 1.35
2 years	0.28 $\pm$ 0.55	0.39 $\pm$ 0.80	0.70 $\pm$ 1.86	0.74 $\pm$ 2.37
Overall	0.51	0.44	1.16	1.17

Table 2 Overall values of migration at the 2-year follow-up of the three reinforcement rings showing progressive translation and/or rotation. Post-operative implant position is used as baseline value. Patient 904 was symptomatic with conventional radiographs

Patient code	Proximal translation (mm)	Lateral translation (mm)	Rotation longitudinal axis (degrees)	Rotation sagittal axis (degrees)
904	2.37	3.58	5.80	9.83
913	0.12	0.06	6.79	5.86
914	0.23	0.48	2.78	0.22

axis (inclination in the frontal plane). Post-operative position of the implant is used as baseline value

showing broken screws and hook; patient 913 was asymptomatic; patient 914 was symptomatic with bone-scan suggesting aseptic loosening

seen in a consecutive series of 92 dysplastic hips treated in the last decade using the RR with hook [2]. The current (4%) and predicted failure rates based on RSA assessment (12.5%) of the present study compares favourably with short- and, respectively, long-term reports in the literature [2, 8]. Measurements on conventional radiographs show an accuracy of 0.5–5 mm and 1–6°, depending on the technique employed, the anatomic region investigated and the number of examiners. RSA can be performed with an accuracy of 10–250 µm of linear displacement and 0.03–0.6° of rotation [11, 20]. It has been shown that RSA can detect implant migration before onset of clinical and radiological signs of loosening and that there is a good correlation between increased displacement rates during the first 2 years after THR and late failure of fixation [11, 13]. RSA was developed by Probst in Germany and Selvik in Sweden in the early 1970s and has been used extensively to evaluate the migration of different types of THR components [1, 11, 12, 19, 20], but so far, no investigation of the RR in hip dysplasia has been performed using this technique.

The RR facilitates reproducible reconstruction of the anatomic hip centre by positioning the hook around the inferior margin of the acetabular floor (incisura acetabuli), a consistent landmark despite severe deformity and bone-stock deficiency. Several clinical studies show that implant placement in the true acetabulum is essential to restore the function of the abductor mechanism and to achieve adequate host-bone coverage [14, 22, 24]. In contrast, poor long-term results have been reported when THR was performed with high hip-joint centre [7, 15, 25]. The hook does not act as a fixation device but helps prevent high or lateral placement of the ring and helps adequate coverage of the polyethylene liner, regardless of the degree of anatomical deformity. Intra-operative image intensifier is recommended to check correct hook positioning around the radiological teardrop. RR positioning for range of motion purposes is not as critical as it is with a standard acetabular component because of the freedom to fix with cement the polyethylene liner in the optimal anatomical orientation. Additional advantages of the RR are cementing of the liner, which avoids back-side polyethylene wear, and impaction of the bone graft between host bone and ring, providing permanent loading and preventing post-operative resorption [18].

In conclusion, at a minimum follow-up of 2 years, 93% of the RR appeared clinically and radiologically stable and RSA showed low rates of linear translation and rotation in 87.5% of implants. The RR with hook provides adequate stability in poor bone-stock settings and prevents bone-graft resorption.

References

- Alfaro-Adrian J, Gill HS, Marks BE, Murray DW (1999) Mid-term migration of a cemented total hip replacement assessed by radiostereometric analysis. *Int Orthop* 23:140–144
- Bayan A, Orec R, Pitto RP (2004) Bone grafting and reinforcement ring with hook for acetabular dysplasia. *J Bone Joint Surg Br [Suppl]* (in press)
- Charnley J (1979) Low friction arthroplasty of the hip. Springer, Berlin, Heidelberg, New York
- Crowe JF, Ranawat CS (1979) Total hip replacement in congenital dislocation and dysplasia of the hip. *J Bone Joint Surg Am* 61:15–23
- Dai X, Omori H, Okumura Y, Ando M, Oki H, Hashimoto N, Baba H (2000) Bone grafting in cementless total hip replacement for congenital dysplasia of the hip. *Int Orthop* 24:260–263
- Freeman MAR (1999) Radiolucent lines. A question of nomenclature. *J Arthroplasty* 14:1–2
- Gill TJ, Sledge JB, Müller ME (1998) Total hip arthroplasty with use of an acetabular reinforcement ring in patients who have congenital dysplasia of the hip, results at five to fifteen years. *J Bone Joint Surg Am* 80:969–977
- Gill TJ, Siebenrock K, Oberholzer R, Ganz R (1999) Acetabular reconstruction in developmental dysplasia of the hip. Results of the acetabular reinforcement ring with hook. *J Arthroplasty* 14:131–137
- Glyn-Jones S, Hicks J, Alfaro-Adrian J, Gill HS, McLardy-Smith P, Murray DW (2003) The influence of cement viscosity on the early migration of a tapered polished femoral stem. *Int Orthop* 27:362–365
- Johnston R, Fitzgerald RH Jr, Harris WH, Poss R, Müller ME, Sledge CB (1990) Clinical and radiographic evaluation of total hip replacement, a standard system of terminology for reporting results. *J Bone Joint Surg Am* 72:161–168
- Kärrholm J (1997) Radiostereometry of hip prostheses. *Clin Orthop* 344:94–110
- Kärrholm J, Snorrason F (1992) Migration of porous coated acetabular prostheses fixed with screws. *J Orthop Res* 10:826–835
- Krismer M, Stöckl B, Fischer M, Bauer R, Mayrhofer P, Ogon M (1996) Early migration predicts late aseptic failure of hip sockets. *J Bone Joint Surg Br* 78:422–426
- Linde F, Jensen J, Pilgaard S (1988) Charnley arthroplasty in osteoarthritis secondary to congenital dislocation or subluxation of the hip. *Clin Orthop* 227:164–170
- MacKenzie JR, Kelley SS, Johnston C (1996) Total hip replacement for coxarthrosis secondary to congenital dysplasia and dislocation of the hip. *J Bone Joint Surg Am* 78:55–61
- Nivbrant B, Kärrholm J, Önsten I, Carlsson A, Snorrason F (1996) Migration of porous press-fit cups in hip revision arthroplasty. A radiostereometric 2-year follow-up study of 60 hips. *J Arthroplasty* 11:390–396
- Pitto RP, Schmidt R (1998) Die Primärstabilität zweier Pfannendachschalen und einer Pfannenstützschale. Einfluß von knöchernen Defekten. *Biomed Eng* 43:210–215
- Pitto RP, Di Muria GV, Hohmann D (1998) Impaction grafting and acetabular reinforcement in revision hip replacement. *Int Orthop* 22:161–164
- Probst KJ, Baacke M (1976) Röntgenstereoverfahren in der orthopädie. *Orthopäde* 5:195–204
- Schwämmlein D, Schmidt R, Willmann G, Holzwarth U, Pitto RP (2000) Migration patterns of press-fit cups with polyethylene or alumina liner. A randomized clinical trial using radiostereometric analysis. In: Garino J, Willmann G (eds) *Bioceramics in total joint arthroplasty*. Thieme, Stuttgart 81–85
- Sharp IK (1961) Acetabular dysplasia. The acetabular angle. *J Bone Joint Surg Br* 43:268–272
- Stringa G, Pitto RP, Di Muria GV, Marcucci M (1995) Total hip replacement with bone grafting using the removed femoral head in severe acetabular dysplasia. *Int Orthop* 19:72–76
- Thanner J, Kärrholm J, Malchau H, Herberts P (1999) Porous cups with and without hydroxylapatite-tricalcium phosphate coating. 23 matched pairs evaluated with radiostereometry. *J Arthroplasty* 14:266–271
- Yoder SA, Brand RA, Pedersen DR, O’Gorman TW (1988) Total hip acetabular component position affects component loosening rates. *Clin Orthop* 228:79–85
- Zlatic M, Radojevic B, Lazovic C (1990) Reconstruction of the hypoplastic acetabulum in cementless arthroplasty of the hip. *Int Orthop* 14:371–375