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Résultats à 10 ans minimum de l'implantation d'une tige fémorale non cimentée et sur mesure dans le cas de dysplasie Crowe III et IV lors d'une prothèse totale de la hanche en un temps, sans ostéotomie sous-trochantérienne

Hitz Olivier

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UNIVERSITÉ DE LAUSANNE - FACULTÉ DE BIOLOGIE ET DE MÉDECINE
Département de chirurgie
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Résultats à 10 ans minimum de l'implantation d'une tige fémorale non cimentée et sur mesure dans le cas de dysplasie Crowe III et IV lors d'une prothèse totale de hanche en un temps, sans ostéotomie sous-trochantérienne

THESE

préparée sous la direction du Professeur Alain Farron
(avec la co-direction du Professeur Jean-Noël Argenson)

et présentée à la Faculté de biologie et de médecine de
l'Université de Lausanne pour l'obtention du grade de

DOCTEUR EN MEDECINE

par

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Résultats à 10 ans minimum de l'implantation d'une tige fémorale non cimentée et sur mesure dans le cas de dysplasie Crowe III et IV lors d'une prothèse totale de hanche en un temps, sans ostéotomie sous-trochantérienne

Lausanne, le 20 septembre 2018

pour Le Doyen
de la Faculté de Biologie et de Médecine

Monsieur le Professeur John Prior
Vice-Directeur de l'Ecole doctorale

Résumé en français du travail de thèse (article, enjeu, contexte de la recherche, conclusions et perspectives)

Lors de mon activité clinique en 2017 aux Hôpitaux universitaires Sud de Marseille j'effectue, sous la supervision du Professeur Argenson, un suivi rétrospectif non randomisé de patients souffrant de dysplasie développementale de hanche (DDH) de haut grade (Crowe III ou IV) ayant été traités avec prothèse totale de hanche (PTH) en un temps opératoire avec tige fémorale non cimentée faite sur mesure. Il n'existe pas de publication relatant des résultats à long terme pour des implants fémoraux sur mesure utilisant une seule technique opératoire pour ce type de malades. Peu de centres disposent de données suffisantes, vu le nombre restreint de patients Crowe III/IV. La prise en charge dans les pays développés se faisant plus tôt que par le passé.

Les options pour l'implantation d'une PTH en cas de DDH haut grade incluent l'ostéotomie sous-trochantérienne avec raccourcissement fémoral (risque de mauvaise consolidation, risque d'inégalité de longueur des membres inférieurs important), le haut positionnement du centre de la hanche (risque de descellement augmenté), la chirurgie en deux temps avec abaissement progressif utilisant un fixateur externe avant PTH (risque d'infection accru, séjour hospitalier prolongé). Les résultats à long terme sont très hétéroclites dans la littérature. Pour des raisons biomécaniques et biologiques le centre de rotation original devrait être conservé et par conséquent la réduction ouverte pour restaurer la longueur du membre inférieure sans lésion neurologique est difficile. Nous avons décrit les résultats à long terme d'une technique en un temps opératoire par un abord de Watson-Jones sans ostéotomie sous-trochantérienne utilisant une tige sur mesure non cimentée et fréquemment associée à des ténotomies séquentielles pour l'abaissement du fémur et à une ostéotomie du grand trochanter quand l'antéversion fémorale est excessive. Pas de libération des muscles abducteurs, du tenseur du fascia lata ou du nerf sciatique. Une autogreffe de la tête fémorale est utilisée si la couverture de l'acétabulum est insuffisante. Les composants prothétiques employés sont une cupule en titane non cimentée recouverte d'hydroxyapatite toujours placée dans l'acétabulum anatomique (Hilock Rev, Symbios), un insert UHWP avec rebord, une tête céramique, une tige sur mesure en titane non cimentée recouverte d'hydroxyapatite (Symbios). Collecte-analyse des données cliniques/radiologiques et soumission des travaux à Journal of Arthroplasty le 15 décembre 2017 (5-year impact factor 3.146, SJR 2.373).

98 PTH ont été effectuées à Marseille en utilisant cette technique, dont 26 hanches sont des DDH de haut grade avec un suivi moyen sur 16 ans. Cela concerne 23 patients avec une moyenne d'âge de 45 ans, une taille moyenne de 160 cm et un poids moyen de 69 Kg. L'allongement moyen désiré selon planification et tenant compte des déformations de la colonne, des genoux et des pieds est de 32 mm (3-80). L'antéversion fémorale moyenne est de 21 degrés (8-46). Le Student's t-test est utilisé pour les variables continues et une analyse de Kaplan-Meier pour la survie des implants (tige, cupule, polyéthylène) en regard des motifs de révision (descellement aseptique, défaillance mécanique ou usure). Le Harris Hip Score moyen augmente significativement de 49 à 86 points. La satisfaction des patients avec un score subjectif d'auto-évaluation est pour 65% excellent et pour 35% bien. 17 patients marchent sans canne. 20 hanches ne présentent aucune douleur. 10 hanches ne présentent aucune boiterie, 10 une discrète, 5 une modérée et 1 une boiterie sévère. Il n'y a aucune corrélation entre le fait de marcher avec des cannes, la boiterie ou le score subjectif d'auto-évaluation. La différence moyenne de longueur des membres inférieurs est de 36 mm (3-80) préopératoire et de 7 mm (0-17) postopératoire.

Parmi les complications: une lésion transitoire du nerf sciatique et une du nerf fémoral avec récupération complète à 18 et 11 mois, deux luxations récidivantes traitées l'une par repositionnement du polyéthylène et l'autre par révision de la cupule pour meilleur repositionnement, une non-union du grand trochanter qui a nécessité une ORIF. 5 autres révisions ont été effectuées : une cupule a été changée pour descellement aseptique à 95 mois, une tige a été changée suite à une fracture Vancouver B2, deux tiges ont été changées pour descellement aseptique à 111 et 161 mois, un polyéthylène a été remplacé à 132 mois pour usure symptomatique. Pas d'infection, pas de lésion vasculaire, pas de fracture intraopératoire. On constate radiologiquement lors du dernier contrôle une ligne radiolucente non progressive acétabulaire dans la zone 1 sur une hanche. Une ostéolyse fémorale asymptomatique sur deux hanches dans la zone 1. Des ossifications hétérotopiques grade 1 sur une hanche. Pas de critère pour une mauvaise ostéointégration de la tige, une instabilité de la cupule ou une mauvaise ostéointégration de la greffe acétabulaire. L'analyse de survie à 15 ans concernant le descellement aseptique de la tige est de 87,5% et de la cupule de 96,1%.

La combinaison d'un bon ancrage intramédullaire et d'une bonne adaptation extramédullaire concernant l'offsetet l'antéversion fournie par la tige sur mesure permet d'éviter des procédures chirurgicales supplémentaires et un programme de réhabilitation accéléré. Le surcoût de l'implant fémoral sur mesure est compensé par un court séjour hospitalier et par l'absence d'un ancillaire. Malgré le petit nombre de patients et le design rétrospectif de l'étude, la fonction clinique, le peu de complications neurologiques et la survie à long terme signalées dans cette série sont encourageantes pour ce groupe de patients ayant développé une coxarthrose secondaire. Au vu de la rareté des cas il paraît difficile de pouvoir effectuer une étude prospective randomisée.

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Primary Arthroplasty

Minimum 10-Year Outcome of One-Stage Total Hip Arthroplasty Without Subtrochanteric Osteotomy Using a Cementless Custom Stem for Crowe III and IV Hip Dislocation

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ABSTRACT

Background: Options for total hip arthroplasty (THA) in high dislocated hips include subtrochanteric osteotomy (STO), high hip center positioning, and 2-stage surgery with progressive lowering using an external fixator before THA. We described the long-term results of 1-stage THA performed without STO, using a cementless customized stem associated if necessary with sequential tenotomies and/or greater trochanteric osteotomy.

Methods: Ninety-eight consecutive THA without STO were performed using this technique. Of those 98 hips, 26 hips with high dislocation (12 class III and 14 class IV according to the Crowe classification) were evaluated at an average follow-up of 16 (10-22) years.

Results: At the time of last follow-up, the mean Harris Hip Score was 86 points (37-100). The mean leg-length discrepancy was 7 ± 5 mm (0-17). Two transient (7.7%) nerve palsies (1 sciatic and 1 femoral) were notified. A revision was required for 6 hips (23.1%). Kaplan-Meier survivorship analysis at 15 years regarding aseptic loosening of the femoral component was 87.5% (95% confidence interval, 76.5-99.1). During the same period, acetabular implant survivorship free from revision for aseptic loosening was 96.1% (95% confidence interval, 92.7-99.9).

Conclusion: The combination of intramedullary fit and extramedullary adaptation for offset and anteversion provided by the custom stem can avoid additional procedures associated to THA in high developmental dysplasia of the hip. The clinical function and long-term survival reported in this series is encouraging for THA performed in case of high hip dislocation.

Total hip arthroplasty (THA) for neglected developmental dysplasia of the hip (DDH) is a technically demanding procedure for arthroplasty surgeons [1–3]. The placement of the acetabular component in the true acetabulum is considered to be the ideal choice for biomechanical and biological reasons [4–12]. It can, thus, be challenging to reduce the hip joint and achieve leg-length restoration while avoiding neurologic traction injury [13,14]. Therefore, to overcome contractures and to reduce the hip without stretching the sciatic nerve, femoral shortening has been introduced by Paavilainen et al [15] and Eskelinen et al [16] as an adjunct to THA. Several authors have reported long-term results of THA for high DDH performed using shortening osteotomy [16–21]. To avoid the complications related to osteotomy, recent reports documented 2-stage progressive femoral lowering followed by a cementless THA (Yoon et al [22], Binazzi [23]). However, only few papers have documented the long-term results of isolated cementless THA in such etiology (Crowe III and IV) [24,25] and none using isolated custom stems. In the review by Tsiampas et al [26], the long-term series mentioned in the article with custom-made femoral implants was not only focused on high DDH but also combined femoral shortening osteotomy was used intermittently. The

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purpose of the present retrospective study is to report the clinical and radiographic minimum 10-year outcome of THA for Crowe III and IV DDH using a customized stem without shortening osteotomy, associated with sequential tenotomies and/or greater trochanter osteotomy if needed.

Methods

Patients

Ninety-eight one-stage THAs for late DDH (82 patients) were performed at a single institution. The Crowe classification has been used to assess the magnitude of subluxation of the femoral head [14]. This classification includes 4 types: I (<50% subluxation), II (50–75% subluxation), III (75–100% subluxation), and IV (100% subluxation). Of those 98 hips, 26 hips (23 patients) were classified according to the Crowe classification as type III (n = 12) and IV (n = 14) and were followed up from 1990 to 2013. There were 18 females and 5 males. The mean age at the time of the procedure was 45 ± 12.3 (17-63) years. The average height was 160 ± 6.2 (150-170) cm, and the average weight was 69 ± 12.8 (46-118) kg. There were 13 left hips and 13 right hips. Thirteen hips (50%) had a previous surgery on the considered hip, including 6 shelf arthroplasties, 5 intertrochanteric osteotomies, 1 open reduction, and 1 Chiari pelvic osteotomy. The mean follow-up was 16 (10-22) years.

Preoperative Planning

The preoperative planning included anteroposterior (AP) pelvic view, AP and lateral view of the considered hip, full frontal view of the lower limbs, positioning the patient supine, and a computed tomography (CT) scan. A 3-dimensional reconstruction of the internal and external geometry of the femur was created based on digital imaging and communications in medicine format images obtained from a CT scan that included the acetabular roof proximally to the posterior femoral bicondylar axis distally [27,28]. In presence of structural changes in the lumbosacral spine, malalignment of the ipsilateral knee and/or equinus foot, a lateral view of the lower limbs was obtained. The mean preoperative leg-length discrepancy (LLD) was 36 ± 26 (3-80) mm. According to the Crowe classification, the mean preoperative LLD was 27 ± 20 (3 to 60) mm and 45 ± 29 (5-80) mm, respectively, in type III and IV ($P = .003$). Taking into account the spine, knee, and/or foot abnormalities, the desired lengthening was 32 ± 26 (3-80) mm, with 24 ± 18 (3 to 58) mm and 45 ± 29 (5 to 80) mm for Crowe type III and IV, respectively ($P = .004$). The mean preoperative anteversion of the proximal femur was 21° ± 13° (8°-46°).

Surgical Technique

All the procedures were performed under general anesthesia by a senior surgeon using the anterolateral Watson-Jones approach in supine position without a traction table. Greater trochanteric osteotomy (GTO) was performed in 6 hips (23%) with lateral repositioning when excessive femoral anteversion was present to relocate the abductor muscles action line and avoid a posterior position. Sequential tenotomies were performed if needed for lowering of the femur including adductor or iliopsoas tenotomy (22 hips, 85%). Once the psoas insertion was released, the femoral head-neck resection could be performed at the level of the lesser trochanter to ensure a complete capsule detachment. No abductor or fascia lata muscles release, intertrochanteric shortening or rotational femoral osteotomy was performed, and no external fixator was used. No sciatic nerve tension assessment or release was performed. In all cases, an hemispheric press-fit uncemented titanium alloy, hydroxyapatite (HA)-coated acetabular component (Hilock Rev, Symbios, Yverdon, Switzerland) was implanted in the true acetabulum with a hook placed in the obturator foramen and 2 screws in the acetabular roof. Autogenous femoral head grafts were used to provide additional superolateral acetabular coverage in 7 hips (27%), 3 in Crowe III (3 of 12, 25%), and 4 in Crowe IV (4 of 14, 29%). A conventional ultra-high-weight polyethylene 20° elevated liner was used in association with a ceramic head. The average diameter of the cup was 46 (36-56) mm. A 3-dimensional cementless custom HA-coated titanium femoral component (Symbios, Yverdon, Switzerland) has been used for all patients fitting the intramedullary proximal femoral anatomy and accommodating the 3-dimensional offset of the femoral neck to obtain the correct hip center [3,27,29]. GTO, when performed, was stabilized with 3 cerclages with the lower limb in abduction. After skin closure and wound management, a pillow was used to position the lower limb in abduction and flexion, when an intraoperative contracture was present after THA reduction. Neurologic and vascular complications were immediately assessed in the recovery room.

Postoperative Management

All patients were mobilized on the first day after THA, sitting on bed. On the second day, they were asked to stand up, helped by a physiotherapist, and on the third day, they were allowed to walk with partial weight bearing protected by 2 crutches. The 2 crutches were used for 6 weeks in case of greater trochanter osteotomy, without active abduction workout, and for 3 weeks, when no greater trochanter osteotomy was performed, and a single crutch on the opposite side was required for 3 additional weeks. No brace was used. Exercises focused on passive and then active recuperation of ROM. Routine thromboprophylaxis was used with low-molecular-weight heparin preoperatively and postoperatively for 3 weeks.

Clinical and Radiographic Evaluations

Clinical evaluation was performed using the Harris Hip Score (HHS) [30] preoperatively and postoperatively. A 5-scale satisfaction score was used (patients rated their hip status as excellent, good, fair, poor, and disappointing). The presence of intraoperative or postoperative complications including infection, nerve palsy, dislocations, or loosening was recorded. Standard AP and lateral radiographs performed at the most recent follow-up examination were compared with the first postoperative radiographs. The assessment criteria were the osteointegration of the femoral component according to Engh and Bobyn [31], radiolucent lines and periprosthetic osteolysis in the femur according to the 7 zones from the study by Gruen et al [32], the presence of radiolucent lines at the acetabular-bone interface according to DeLee and Charnley [33], the stability of the acetabular component as described by Zicat et al [34] in each of the 3 zones from the study by DeLee and Charnley [33], the acetabular graft osteointegration according to Conn et al [35], the grade of heterotopic ossification according to Brooker et al [36], and the fusion at the site of greater trochanter repositioning.

Statistical Methods

Data are presented as mean values with ranges. The Student's *t* test was used for comparisons of continuous variables. *P* value < .05 was significant. Kaplan-Meier survivorship analysis [37] was performed with 2 end points: (1) revision for any reason and (2) revision for aseptic loosening, mechanical failure, or wear. Statistical analysis was performed using SPSS software (IBM, Armonk, New York).

Results

The mean HHS of the 23 patients (26 hips) increased significantly from preoperative (49 ± 22 points) to the most recent follow-up examination (86 ± 13 points; $P < .0001$). At the last follow-up, the mean HHS pain subscore was 41 ± 5 points, with 20 hips (77%) showing no pain. Seventeen patients (74%) walked without any aid. Ten hips (38.5%) did not show any limping, 10 (38.5%) had a slight, 5 (19.2%) a moderate, and 1 (3.8%) a severe limping. Using the subjective satisfaction self-evaluation, 15 patients (65%) rated their results as excellent and 8 (35%) as good. No correlation was found between patients using a walking aid, limping, and their satisfaction evaluation.

The mean LLD was 7 ± 5 (0-17) mm. There were 2 (7.7%) transient nerve palsies (1 sciatic and 1 femoral). The sciatic nerve palsy was recorded in a 38-year-old female with a bilateral Crowe IV DDH that had a previous shelf arthroplasty only on the right side. She underwent 2 sequential THAs with planed lengthening of 48 mm on the right side and 53 mm on the left side. The nerve palsy was recorded on the right side and resolved completely at 18 months. The HHS was 87 at the final follow-up, and the satisfactory evaluation was rated as good. The second was a femoral palsy which resolved in 11 months. It was a 51-year-old female with a right Crowe IV DDH and a lengthening to be realized of 29 mm. She did not have previous surgery on the considered hip. The HHS was 88 at the final follow-up, and the satisfactory evaluation was rated as good.

Two patients (8.7%) had recurrent hip dislocations. The first one was a 63-year-old woman with a left Crowe III DDH. She was treated by repositioning of the elevated liner and did not have any other subsequent dislocation. The final HHS was 77 and her satisfaction evaluation was rated as good. The second one was a 17-year-old female who underwent a THA for a Crowe III DDH who required an early cup revision for better positioning. The final HHS was 97 points, and the satisfaction evaluation was rated as good. One hip (3.8%) had a symptomatic greater trochanter nonunion which required an open reduction and internal fixation. The final HHS was 91, but a crutch was required to walk. All the acetabular components were located in the true acetabulum without detectable migration (Fig. 1).

The radiographic analysis at the last follow-up showed a nonprogressive radiolucent line around the acetabular component in zone 1 in 1 hip (3.8%) according to DeLee and Charnley [33]. An asymptomatic femoral osteolysis was present in 2 hips (7.7%) in zone 1 according to Gruen [32]. Heterotopic ossifications were observed in 1 hip (3.8%) and were classified as grade 1 according to Brooker et al [36]. No pronounced resorption was noted around the femoral components according to Engh and Bobyn [31]. All acetabular components were considered as stable according to Zicat et al [34]. All cases with acetabular graft showed a good osteointegration according to Conn et al [35].

A revision was needed in 6 hips (23.1%). In addition to the early cup revision for instability mentioned previously, 1 cup was revised for aseptic loosening at 95 months. In 3 hips (11.5%), the stem was revised: 1 for a Vancouver B2 fracture (acute trauma) and 2 (7.7%) for aseptic loosening at 111 and 161 months. In 1 hip (3.8%), the liner was changed for symptomatic wear at 132 months.

Kaplan-Meier survivorship analysis at 15 years of the femoral component considering revision for aseptic loosening as the end point was 87.5% (95% confidence interval, 76.5-99.1) (Fig. 2). For the acetabular implant considering aseptic loosening as the end point, survivorship was 96.1% (95% confidence interval, 92.7-99.9) (Fig. 3). Survivorship analysis at 15 years for both implants was 72.6% (95% confidence interval, 45.3-99.9) regarding any reason as the end point. The number of hips at risk for revision was 10 at 15 years.

Discussion

Several techniques have been described to address end-stage osteoarthritis in Crowe type III or IV DDH using THA. The key aspect for achieving long-term stability of the acetabular component relies on excellent coverage of the cup and restoration of the center of rotation of the hip into an anatomical position [7]. Linde et al [38] reported that at a mean follow-up of 9 years, the placement of the acetabular component in the true acetabulum produced a much lower loosening rate than placement above the true acetabulum (13% and 42%, respectively). Pagnano et al [8] found that positioning of the cup proximal to the true acetabular region was associated with substantial increase in loosening. These observations indicate that the acetabular component should be positioned in the true acetabular region in patients with high DDH. The present study, using a 1-stage surgical technique without subtrochanteric osteotomy (STO), has shown that all the acetabular components were located in the true acetabulum without detectable migration and a 96.1% cup survival at 15 years of follow-up. The

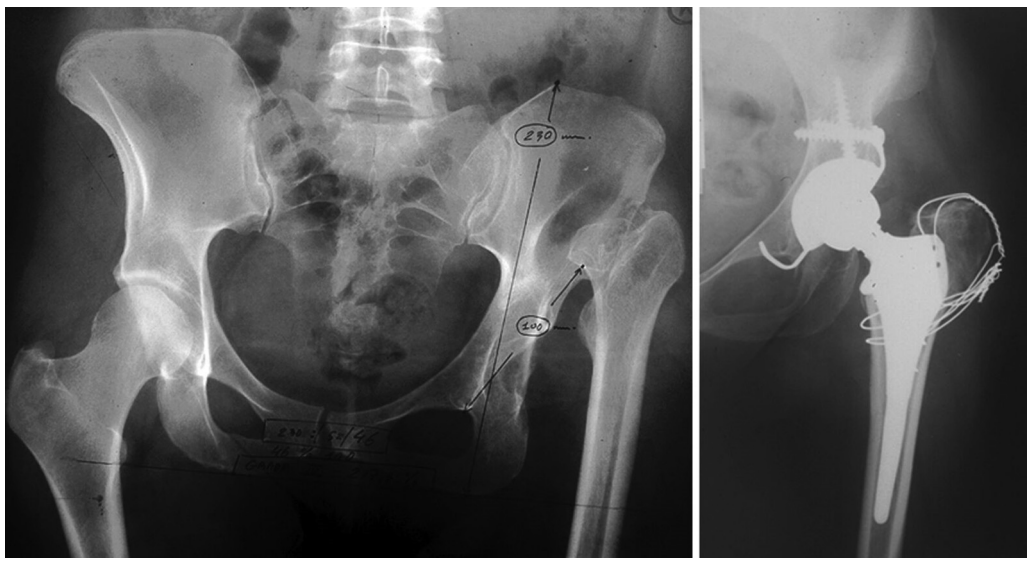

Fig. 1. Crowe IV DDH with greater trochanter osteotomy and 38-mm lengthening.

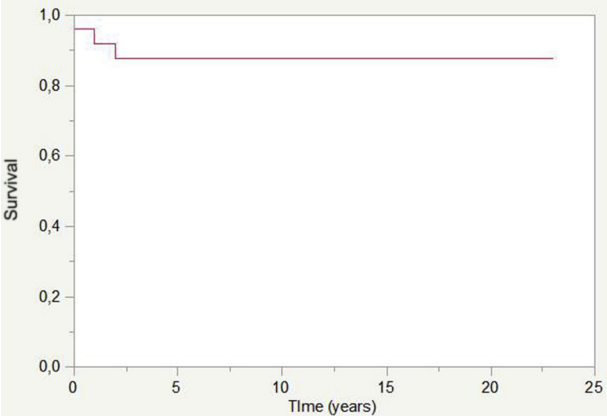

Fig. 2. Kaplan-Meier curve showing 87.5% survivorship free from stem revision regarding aseptic loosening at 15 years.

custom stem used in this series of THA for high hip dislocation provides anatomical fit and 3D neck correction for anticipating surgical difficulties found in this etiology related to proximal femoral anatomy. The clinical results are encouraging in a young and active population while exhibiting satisfactory lower limb equalization and limited neurological complications.

Anatomic socket placement can make hip reduction difficult and reduction may require considerable limb lengthening associated with increased risk of neurological injury [13,14]. Therefore, femoral shortening has been proposed to facilitate reduction and protect the sciatic and femoral nerves. It is a 1-stage technique, using the femoral component for intramedullary stabilization that also allows for correction of a severe anteversion of the femoral neck. However, the procedure remains challenging as incongruences may appear between the proximal and distal canal diameters after shortening osteotomy leading to difficulties for achieving a secure fixation; these difficulties might increase the risk of delayed union or nonunion of the osteotomy [18,27,29,39–41]. While Ollivier et al [19] mentioned for Crowe IV patients a nonunion rate at femoral shortening osteotomy site of 7%, Mutlu et al [42] reported in Crowe III and IV patients either 18.6% nonunion or 20.9% delayed union depending on the type of cementless stem used. Kawai et al [43] using cemented stems mentioned an average time to union of the osteotomy site of 4.9 (3-8) months and that full weight bearing was allowed after 12-16 weeks. Using cementless stems, weight bearing is usually carefully increased depending on the consolidation of the osteotomy site

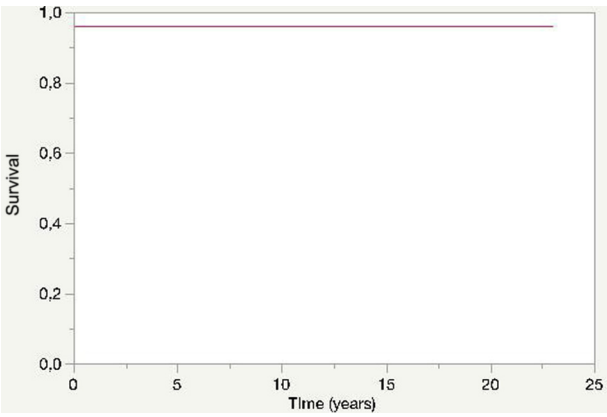

Fig. 3. Kaplan-Meier curve showing 96.1% survivorship free from cup revision regarding aseptic loosening at 15 years.

starting at 6 weeks and fully completed at 12 weeks according to several authors [16,17,44–47]. In the present series without STO, patients were allowed to walk with partial weight bearing at day 3 with the help of 2 crutches and full weight bearing was normally applied after 3 weeks if a GTO was performed.

Additional complications related to the procedure have been described as nerve palsies [39–41,48,49], intraoperative femoral fracture [13,18,29], and dislocation [13,18,40,41,49]. Mu et al [50] using cementless Zweymüller THA with STO in 71 Crowe IV patients mentioned 1 case of complete and 7 cases of transient nerve palsies, 1 cup loosening, 4 polyethylene wear and 1 cup breakage, 1 dislocation, and 20 intraoperative fractures. In the present series using custom stems, we did not find any intraoperative fracture, probably in relation with the adaptation between the stem and the proximal modified anatomy often found in such etiology. However, the major concern described with the shortening osteotomy technique remains the residual postoperative LLD especially if the DDH is unilateral [13,40,49]. The average 7 (0-17) mm postoperative mean LLD reported in the present series using a custom femoral stem is close to the 6 (0-20) mm reported by Ollivier et al [19] but compares favorably with the other series associating a STO and reporting average LLD from 12 to 14 mm with maximum values ranging from 0 to 60 mm [16,17,45–47].

Long-term results of THA for high DDH with shortening osteotomy showed heterogeneous results. Eskelinen et al [16] followed up 64 hips and reported a 10-year survival rate of 98.4% for the stem and 94.9% for the porous-coated cup, but 8 of the 9 threaded cups were revised. Hartofilakidis and Karachalios [9] followed up 84 hips with cemented or uncemented cups and cemented stems and reported an overall 15-year survival rate of 82.5% for the stem and 86.1% for the cup. Ollivier et al [19] reviewed 28 hips (24 cementless, 4 cementless modular stem and cementless cup) with a mean follow-up of 10 years and reported a 10-year survivorship of the components free of revision of 82%. Reikeras et al [17] followed up 64 hips with uncemented components (straight conical stem full HA and HA or titanium porous-coated cup) at a mean follow-up of 13 years and reported a 15-year survival for any reason of 75% for the cup and 100% for the stem. However, 1 stem subsided after 8 months and was replaced.

Regarding outcomes of THA without shortening osteotomy for Crowe III or IV hips, Kerboull et al [48] using a transtrochanteric approach and cemented components in 83 hips reported a survival rate of 78% at 16 years with revision for any reason as the end point. Numair et al [51] reported higher rates of acetabular revision in completely dislocated hips with cemented components, as compared with dysplastic hips. Chougle et al [52] reported a cup survival rate for aseptic loosening in Crowe IV hips of 60.9% at 10 years. Kawai et al [53] reported a survival rate after transtrochanteric approach and cemented THA of 96.3% at 10 years with any revision surgery as the end point. Using cementless THAs without shortening osteotomy for Crowe III or IV hips, Imbuldeniya et al [24] showed for 25 hips, a survival with revision for any reason of 81% at 15 years with 57% of the patients who had a revision of the acetabular component secondary to polyethylene wear. Proximal osteolysis in zone 1 or 7 around the femoral stem was found in 10 of the 25 hips, all implanted with modular S-ROM stems. Lee et al [25] reported in 27 hips with GTO and various types of cups and stems at a mean follow-up of 15.1 years, a mean LLD of 10 mm, 2 transient peroneal nerve palsies and 2 permanent neurologic deficits (1 femoral, 1 sciatic), 3 intraoperative fractures, and a survival rate for aseptic loosening at 15 years of 90.9% for stem and 52.3% for cup. The use of custom-made stem has been described mostly for low-grade DDH patients [54–56] or with short-term follow-up [57] or were indicated for various femoral deformity etiologies [58]. Benum and Aamodt [55] using occasional subtrochanteric

osteotomies for lengthening reported no case of stem aseptic loosening at 10-year follow-up. Akbar et al [58] reported cup loosening of 5 cups in 72 hips with any progressive femoral osteolysis after a mean follow-up of 14 years.

Although some authors have reported that limb lengthening should be limited to 4 cm [59], Kerboull et al [48] reported that limb lengthening until 7 cm was possible. In our study using an anterolateral approach with sequential tenotomies, it was always possible to reduce the hip into the true acetabulum without the need for a femoral shortening, including the 19 hips (73%) that had a lengthening superior to 4 cm. Two (7.7%) nerve palsies were documented and both recovered. Another option is to perform a 2-stage progressive femoral lengthening followed by a cementless THA. Binazzi [23] documented the clinical radiographic results of 11 patients (12 hips) who were operated with a 2-stage technique at a mean follow-up of 11 ± 5 years with no neurovascular damage or a need for femoral internal fixation and complete limb symmetry. However, 1 hip (8.3%) had a remaining postoperative LLD of 1.8 cm. A potential increased risk of infection remains, owing to the use of an external fixator, and the hospital stay was increased by 2 weeks, corresponding to the time needed for lengthening before the second stage. Yoon et al [22] described a 2-stage operation planned in 6 irreducible hips when expected lengthening of the affected limb after THA was superior to 2.5 cm or when flexion contracture was superior to 30°. Surgical hip release with abductor slide, tensor fascia lata, sartorius muscle, iliopsoas tendon, and rectus femoris release was performed through 2 skin incisions during the first stage. Gradual skeletal traction was thus applied to the operated limb for 2 weeks before performing the THA. However, 5 of 6 hips (83%) were difficult to reduce requiring a subtrochanteric shortening osteotomy to prevent neurologic traction injuries. In the lengthening technique described in the present series, tenotomies of either the adductors or psoas were performed sequentially to reduce the risk of neurological complications. In our experience, a complete muscle function for active flexion and abduction was achieved 6 months after surgery. Eggli et al [60] mentioned that most nerve lesions after leg lengthening occurred by direct or indirect trauma to the nerve during surgery. The incidence of permanent nerve lesion seemed higher without STO in the study by Sonohata et al [61], but nerve palsies are also present with STO techniques. A recent study by Li et al [62] compared 2 groups of Crowe IV patients who underwent cementless THA, one with (20 hips) and one without (22 hips) subtrochanteric shortening osteotomy. The group without femoral shortening osteotomy had a lower postoperative mean LLD and a lower number of patients who developed a limp, more transient femoral nerve palsy (3, all reversible after 6 months), and more knee valgus deformity due to tight soft tissue/iliotibial tract (mostly reversible at the end of follow-up after stretching). The group with osteotomy had one intraoperative fracture and one delayed union at osteotomy site. No sciatic nerve palsy or dislocation was recorded in both groups.

The mean postoperative HHS in the present series using a custom monoblock cementless stem was 86, and the survival at 15 years regarding aseptic loosening was 87.5% for the stem and 96.1% for the cup, all of them implanted in the true acetabulum in a series of Crowe III and IV dislocated hips. The 3D evaluation of the proximal femur anatomy in high DDH [1,27] has shown several important modifications the orthopedic surgeon has to face at the time of THA in such patients compared to primary osteoarthritis [28,29]. The use of custom stem allows fast weight bearing and quick rehabilitation program. Nowadays, the routine use of preoperative CT planning is largely accepted to better assess the 3D anatomy in complex degenerative or traumatic cases to anticipate difficulties during surgery like in THA for high DDH. The 20% additional cost of the custom stem, when compared to off-the-shelf anatomical implant, is hopefully compensated by the reduced length of stay related to immediate weight bearing and the early recovery. This extra cost is also reduced because there is no need for ancillary tools. The 15-year survival, with stable clinical improvement, is encouraging in a group of young patients with a mean age of 45 years, implanted with THA for osteoarthritis secondary to high DDH.

This study has some limitations, including the limited number of patients and its retrospective design; however, THA for high DDH do represent an uncommon and challenging situation for which large prospective studies with a long follow-up are not available. Despite these limitations, the present series is the longest series to date investigating the outcome of cementless THA without shortening osteotomy using a custom stem combined with sequential tenotomies in patients with a high hip dislocation secondary to DDH.

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