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ORIGINAL ARTICLE

Conversion of Arthrodesis to Total Hip Arthroplasty: Clinical Outcome, Complications, and Prognostic Factors of 21 Consecutive Cases

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Abstract *Background:* Although the results of hip arthrodesis compare favorably with those of total hip arthroplasty (THA) in younger patients, long-term consequences such as osteoarthritis of the neighboring joints may necessitate conversion of the arthrodesis to THA. *Questions/Purposes:* The purpose of the present study is to assess mid-term clinical outcome and self-perceived improvement in patients who underwent conversion at our department. Secondary aims were incidence of complications and association between patient characteristics and characteristics of the fusions with the outcome of the procedure. *Patients and Methods:* The study sample comprised 21 cases in 20 patients. Minimum follow-up was 3 years (mean, 8±6.5 years) in 20 cases. Thirteen patients had surgical hip fusions and 7 (8 hips) had nonsurgical fusions. Mean age at the time of conversion was 58.5 years. *Results:* Nineteen out of 21 cases had functioning implants at the latest follow-up visit. According to the Merle d'Aubigné scale, outcome was considered excellent, very good, or good in 15 cases. Lower back pain was reduced in all patients. All but two patients were satisfied after the conversion. The main complications observed included incomplete removal of bone block, intra-operative fractures, dislocation and damage to the femoral artery. Time to conversion and type of fusion had no significant correlation with the clinical outcome. *Conclusions:* Conversion THA is a challenging but successful procedure according to the mid-term clinical outcome observed. Our study suggests that, prognostic factors should be used with caution when establishing indications and post-surgical expectations.

Keywords hip arthrodesis · total hip arthroplasty · conversion

Level of Evidence: Therapeutic, Level IV.

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Introduction

Hip arthrodesis was once considered a definitive operation, and the long-term results compare favorably with those of total hip arthroplasty (THA) in younger patients. However, the long-term consequences of this procedure for neighboring joints often necessitate conversion to THA [11]. Such consequences include osteoarthritis of the spine (60%), ipsilateral knee (30–75%), contralateral knee (15–30%), and contralateral hip (15–30%) [3, 8, 11, 12]. Patients can also be affected by mild or severe limp (>50%), reduced walking speed, instability, and leg-length discrepancy [13].

Conversion to THA is a challenging procedure in which technical difficulties make surgical outcomes less satisfactory than in routine THA [7, 12]. However, in a patient who has spent several decades with a fused hip, this procedure can relieve pain in the back and neighboring joints and improve basic functioning [5, 11].

Prognostic factors are controversial and the most significant are age at takedown, presence of hardware, years from fusion to conversion, intra-articular versus extra-articular arthrodesis, surgical approach, implant selection, and gluteus muscle status [5, 7, 12].

The goals of the present study were: (1) to evaluate the clinical outcome of our conversions of arthrodesis to THA;

(2) to describe the incidence of complications; and (3) to measure the relationship between our clinical results and prognostic factors.

Material and Methods

Between January 1997 and June 2010, we performed 21 conversions in 20 patients (13 female and 7 male). Mean age was 18.8 years (12–37 years) at the time of arthrodesis and 58 years at takedown (21–77 years). Three patients were under 30 at conversion; the rest were over 57. Mean time from arthrodesis to conversion was 39 years (2–65 years).

The reasons for arthrodesis were tuberculosis in eight cases, femoral head necrosis after fracture in three cases, developmental dysplasia of the hip in one case, sequelae of hematogenous septic arthritis in five cases, and Perthes disease in two cases. One male with a bilateral spontaneous fusion was converted to THA in both hips in the same year. The reason for this ankylosis was unknown.

Thirteen patients had surgical hip fusions and 7 (8 hips) had spontaneous fusions, including the patient with bilateral spontaneous ankylosis.

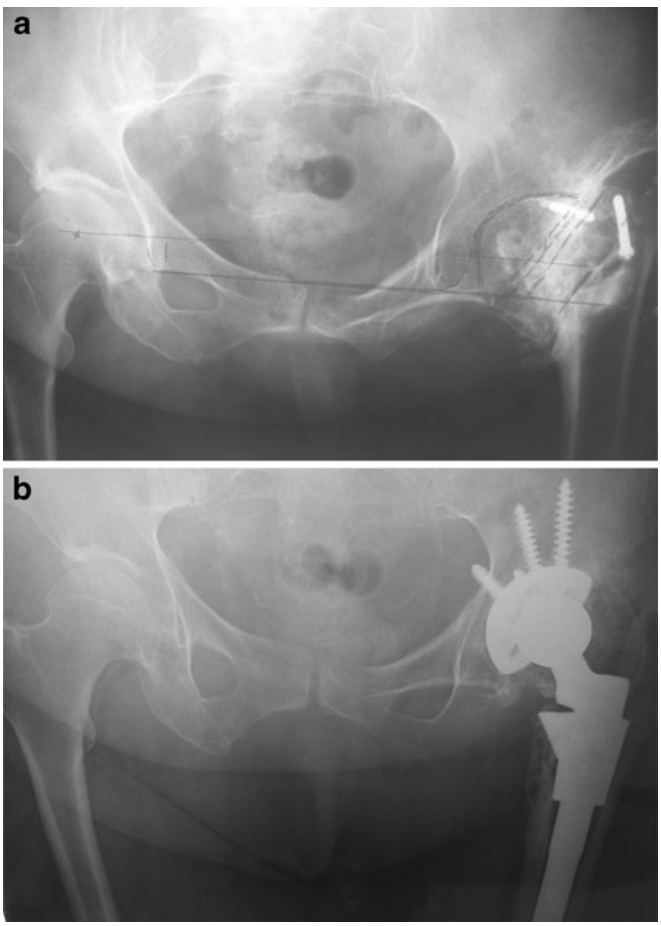

Fig. 1. **a** This preoperative AP pelvic X-ray illustrates an example of an extra-articular arthrodesis. **b** This postoperative AP pelvic X-ray illustrates the technique of THA we used for reconstruction of an extra-articular arthrodesis.

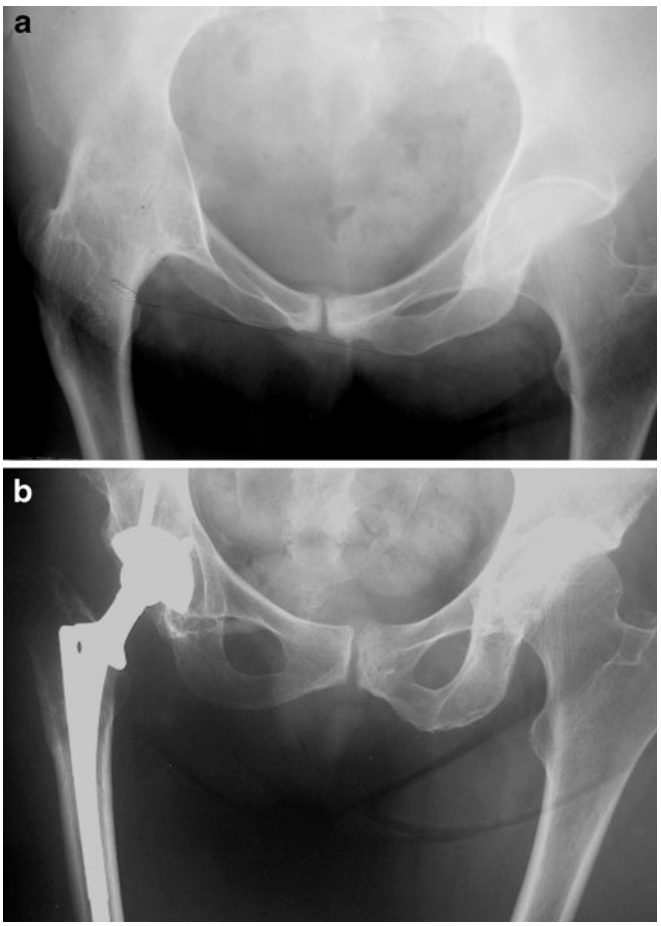

Fig. 2. **a** This preoperative AP pelvic X-ray illustrates an example of an intra-articular arthrodesis. **b** This postoperative AP pelvic X-ray illustrates the technique of THA we used for reconstruction of an intra-articular arthrodesis.

Arthrodesis were classified according to anatomical criteria, rather than to surgical technique (Figs. 1a,b and 2a,b), into: (1) patients with "extra-articular" bone bridges from the lesser or greater trochanter to the ilium or ischium (12 cases); and (2) patients with "intra-articular" bone bridges (9 cases). The latter group maintained the anatomy of the proximal femur. The mean number of previous operations on the ankylosed hips was 3 (range, 0–10).

The main indications for conversion were lower back pain (14 patients) associated with severe degenerative changes and scoliosis (6 cases). Two patients had previously undergone lumbar arthrodesis. Most patients with lower back pain also presented ipsilateral knee pain or contralateral hip pain associated with osteoarthritis. Four patients had ipsilateral knee or contralateral hip pain without marked lower back pain. The arthrodesis failed in two additional patients. One patient sustained a subtrochanteric fracture in a hip fused 60 years ago. Leg-length discrepancies averaged 3.5 cm before surgery (range, 0–10 cm).

At the preoperative evaluation, hardware was present in 13 patients. In most cases, the hardware consisted of a Thornton trilaminar nail. No patients had cobra plates.

Conversions were performed using a standard posterolateral approach without extensile exposure. The fascia was released from the underlying planes and visible hardware removed before proceeding with the dissection. The short rotator muscles were referenced when visible; if not, we performed our dissection "en bloc". At the tip of the greater trochanter we curved our dissection 45º back in order to reach the superior margin of the native acetabulum or to dissect the superior bone block until we reached normal ilium. A 90º angled retractor was gently inserted at the anterior part of the native acetabulum to avoid damage of residual gluteus muscles. With intra-articular fusions, the margin of the femoral neck or bone block is easily identified by palpation and can be delimited with an inferior Hohmann retractor and superior angled retractor. In doubtful cases (e.g., extra-articular fusion), we referenced the bone block with two Steinmann pins (Figs. 3 and 4) and checked with fluoroscopy before resecting it. We directed the saw as horizontally as possible in order to avoid damaging the anterior column. When possible, we preferred cutting first to the femoral rather than to the pelvic side of the fusion or leaving part of the superior bone block in order to maximize the size of the cup and the contact with host bone. In two cases, part of the resection block was re-grafted and fixed in order to gain bone coverage for a larger cup with a larger femoral head (36 mm) (Fig. 5a, b).

We rotated the leg gently until the fusion broke while we levered the femur with two wide osteotomes. When this was not possible, we gained depth with the saw before repeating the gesture. Once the fusion was taken down, we released the femur from the acetabulum and resected the rest of the fusion bone block. All fibrous or bone tissue covering the inferior margin of the native acetabulum was excised. The acetabulum was reamed and the femoral side prepared in the normal fashion with specific modifications for the selected implant.

All patients were operated on using uncemented components. The choice of our brand of implant was restricted to the ones authorized at our institution by blinded public tender. Metaphyseal modular stems (S-ROM, DePuy) and modular cups (Pinnacle, DePuy) comprised our choice of implant in these cases (Table 1). No constrained or dual mobility implants were used.

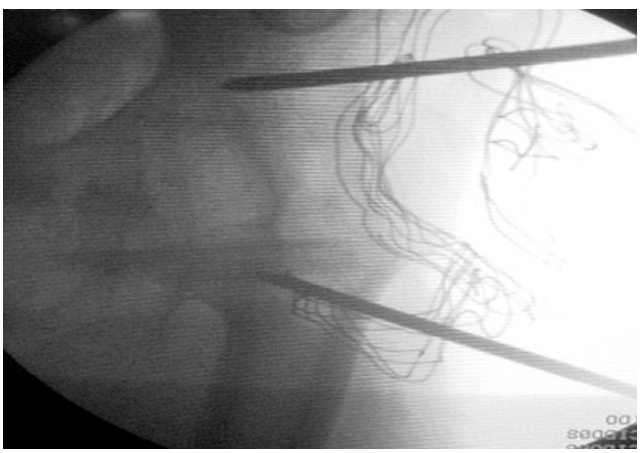

Fig. 3. This intra-operative fluoroscopy illustrates the use of two Steinmann pins as a reference of the bone block in order to guide resection in doubtful extra-articular fusions.

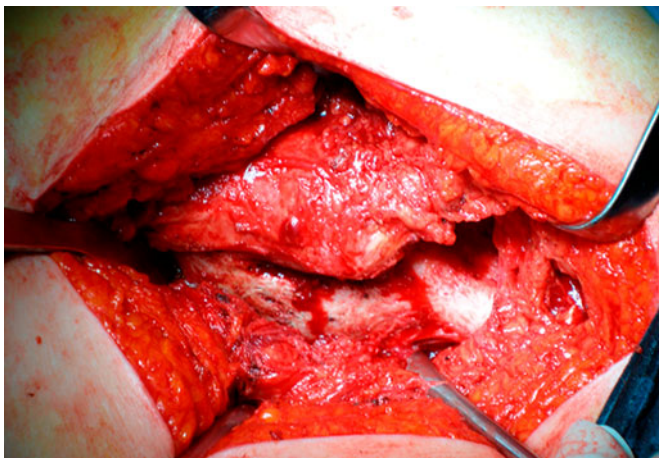

Fig. 4. This intra-operative picture illustrates the use of two Steinmann pins as a reference of the bone block in order to guide resection in doubtful extra-articular fusions.

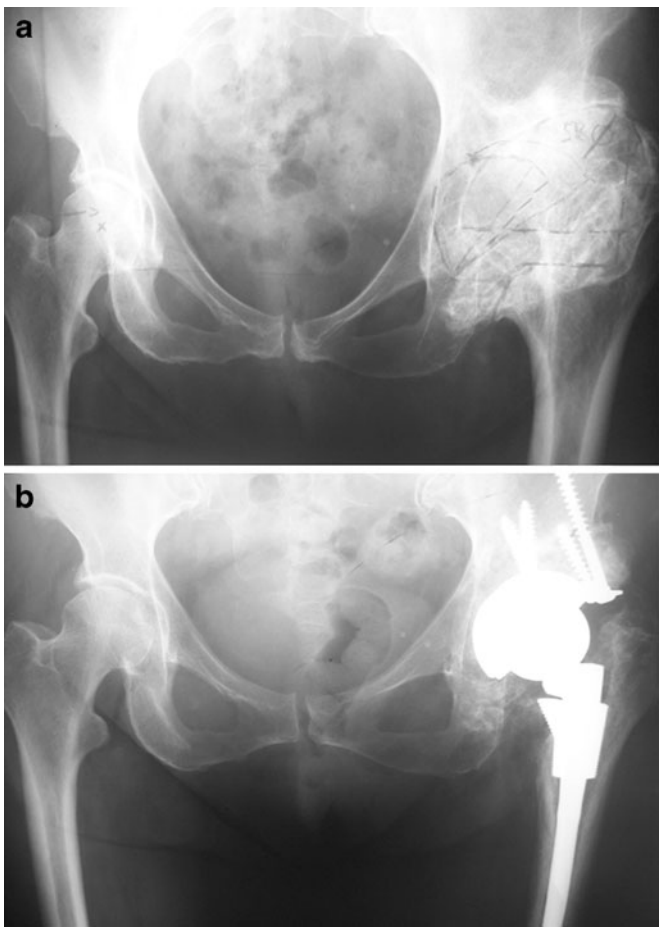

Fig. 5. **a** This preoperative AP pelvic X-ray illustrates an example of an extra-articular arthrodesis and our surgical planning. **b** This postoperative AP pelvic X-ray illustrates a re-grafted and fixed resection block in order to gain bone coverage for a larger cup with a larger femoral head.

Table 1 Profile of the implants used in 21 total hip arthroplasties

Modular	S-ROM (DePuy®)	10
Nonmodular stem	Summit (DePuy®)	3
	Profile (DePuy®)	2
	Multilock (Zimmer®)	1
	AML (DePuy®)	5
Cup	Harris-Galante (Zimmer®)	1
	Pinnacle (DePuy®)	12
	duraloc (DePuy®)	8
Femoral head	22 mm	2
	28 mm	11
	36 mm	8

Fluoroscopic assistance was required in most extra-articular defects.

Abduction orthosis was used in one patient with severe limp because of contralateral poliomyelitis after an early dislocation episode and in another patient with severe limb-length discrepancy and unstable gait [6].

Patients were monitored at 1, 3, 6, and 12 months after surgery and every year thereafter. No patients were lost to follow-up.

Clinical evaluation was performed according to the Merle d'Aubigné Scale [10] at each follow-up visit. Outcomes were classified as excellent (18 points), very good (17 points), good (16 points), fair (15 points), poor (14 points), or bad (≤13 points).

Patient satisfaction after the conversion was categorized as complete, semisatisfied, or unsatisfied.

The statistical analysis was performed using SPSS 11.0 for Windows. Significance was defined as a p value of <0.05. The Merle d'Aubigné score (16–18 points, favorable outcome; 13–15 points, poor outcome) and flexion (≤90º or >90º) were compared with age at fusion (≤18 years or >18 years), age at conversion (≤30 years or >30 years), diagnosis of fusion (post-traumatic, dysplastic, infectious), type of fusion (surgical or spontaneous and extra-articular or intra-articular), main reason for conversion (spinal pain, knee pain, other), and time between fusion and conversion (<10 years, 10 to 40 years, and >40 years).

Results

Nineteen of the 20 patients (20 hips) had a mean follow-up of 8 years (3–14 years). One patient was included with a 2 years follow-up, as she had the worst complication of the series.

At the last follow-up visit outcome was considered excellent in five cases, very good in five cases, good in five cases, fair in two cases, and poor in four cases. Nineteen out of 21 cases had functioning implants. No sockets were revised at the last follow-up visit (Table 2). None of the patients complained of hip pain, including two younger patients who required revision of the stem. Thirteen patients were able to walk with normal gait. Eight patients (38%) had a limp: five had a marked limp requiring a cane and three had a slight limp that did not require a cane (younger patients with unaffected neighboring joints). Pain in the lower back was reduced or almost non-existent in all patients, despite severe scoliosis and degenerative changes. No elective spinal surgery was indicated. Six patients with severe osteoarthritis of the knee required TKA in a second procedure. One patient underwent contralateral revision hip arthroplasty 5 months before conversion. The previous discrepancy was 6 cm. The hip center was not completely restored on the revision side, and lengthening was 3 cm on the conversion side; however, limb-length discrepancy and pelvic tilt were almost corrected (Fig. 6).

Mean range of flexion was 95º (45º–130º), mean internal rotation was 25º (0º–45º), mean external rotation was 35º (15º–60º), and mean abduction and adduction were both 40º (20º–50º). Leg-length discrepancy averaged 3.5 cm before surgery, and mean surgical correction averaged 3 cm (0–5 cm). Pelvic tilt was observed before surgery in 17 cases and, after surgery, it improved or was corrected in 11 of the 17 cases.

Despite the clinical results, all but two patients were completely satisfied after conversion. They reported that their theoretical improvement and functional status had been accurately explained at the preoperative visit. One patient considered the operation to be a failure because she needed a crutch; another was not satisfied because she also required TKA after conversion. Knee pain was her initial reason for consultation, and she had used a crutch before surgery as well. These frustrating cases were operated on at the beginning of the series.

Eight patients (38%) had a perioperative complication in this case series. Complications included incomplete removal of bone block in two cases, heterotopic ossifications in one (Brooker I), two undisplaced fractures of the greater trochanter that did not require cerclage, one incomplete proximal femoral fracture bypassed using the AML stem (DePuy®) without additional measures and one dislocation treated successfully with closed reduction and an abduction orthosis for 3 months. Two of the patients aged <30 years required revision of the stem. The first patient underwent a second procedure 2 years after the index arthroplasty because of protrusion of the stem through the femoral cortex due to an uncorrected varus deformity. She had undergone multiple procedures and, consequently, had an atrophic hip and femur (27 previous procedures on the femur, 10 on the hip). We did not correct her femoral deformity during the first operation. At revision, a femoral osteotomy was performed and bypassed with a Solution Stem (DePuy®), grafted, and cerclaged with Dall–Miles cables (Stryker-Howmedica®). Nine years after the revision arthroplasty, her functional score remains excellent. The second young patient required a revision due to stem loosening 11 years after the index arthroplasty (Multilock, Zimmer®). He underwent osteotomy because of femoral varus remodeling and was retreated with a Solution Stem (DePuy®) combined with a Dall–Miles plate (Stryker-Howmedica®). Five years after the revision arthroplasty he remains pain-free, and his functional score is excellent.

Table 2 Demographic data, clinical results, and complications of 21 cases of fused hips converted to total hip arthroplasty

Age at fusion (years)/Sex	Age at conversion	Diagnosis for fusion	Spontaneous vs surgical fusion	Time to conversion (year)	Intra- vs extra-articular fusion	Reason for conversion	ROM	Merle d'Aubigné	Related procedures	Complications or reoperations	Follow-up (years)
12 F	62	Perthes' disease	Surgical	50	E	Spinal pain (scoliosis) and hip pain	65°	15	No		9
18 F	57	Acetabular protrusion and neck fracture	Surgical	39	E	Ipsilateral knee pain and contralateral hip pain	90°	14	Total knee arthroplasty		9
25 F	62	TBC	Surgical	37	I	Spinal pain and Ipsilateral knee pain	110°	17	Bilateral total knee arthroplasty		10
19 F	21	Sequelae of neck fracture	Surgical	2	I	Failure of fusion	125°	18	Pseudoarthrosis after several procedures	Solution Stem + replacement of polyethylene	14
35 M	75	Septic arthritis	Surgical	40	E	Hip pain	85°	14	Revision contralateral hip	Incomplete removal of bone block	7
12 F	77	Dysplasia	Surgical, modular stem	65	E	Spinal pain	110°	18	No	Incomplete fracture of greater trochanter	6
17 M	58	Perthes' disease	Surgical	41	E	Ipsilateral knee pain and Contralateral hip pain	115°	17	Total knee arthroplasty	Intra-operative proximal periprosthetic fracture. AML stem	12
24 F	28	Septic arthritis	Surgical	4	I	Late failure of the fusion	100°	18	Heterotopic ossification. Nondisplaced fracture of greater trochanter	Stem protrusion though femoral cortex. Solution = stem + cerclage + osteotomy	10
23 F	65	Septic arthritis	Surgical, modular stem	42	E	Spinal pain (scoliosis) and hip pain	130°	18	No		6
13 F	63	TBC	Surgical, modular stem	50	E	Spinal pain (scoliosis) and knee pain	115°	15	Total knee arthroplasty	Femoral artery damage, femoral nerve damage, both resolved	1.5
17 F	64	TBC	Surgical	47	E	Spinal pain (scoliosis) and knee pain	100°	17	No		11
26 M	59	Neck fracture	Surgical	33	E	Ipsilateral knee pain and contralateral hip pain	95°	16	No		11
21 M	63	TBC	Surgical	42	E	Spinal pain and knee pain	110°	16	No		9
14 F	66	TBC	Spontaneous	52	I	Spinal pain and knee pain	85°	16	Total knee arthroplasty. Same side		10
23 M	57	TBC	Spontaneous, modular stem	34	I	Spinal pain, hip pain, knee pain	60°	14	No		7
17 F	28	Septic arthritis	Spontaneous	11	I	Spinal pain (scoliosis) and knee pain	90°	18	No	Dislocation, orthosis	7
13 F	76	Septic arthritis	Spontaneous	63	I	Spontaneous fracture and late non-union	45°	14	No	Incomplete fracture of greater trochanter	3
16 F	68	TBC	Spontaneous	52	I	Spinal pain and hip pain	90°	16	No		8
14 F	67	TBC	Spontaneous	53	E	Ipsilateral knee pain and contralateral hip pain	95°	17	Total knee arthroplasty. Same side	Incomplete removal of bone block	5
23 M	57	Unknown	Spontaneous, modular stem	34	E	Spinal pain (scoliosis), knee pain and hip pain	100°	17	No		4
23 M	57	Unknown	Spontaneous, modular stem	34	I	Spinal pain, knee pain and hip pain	90°	16	No		4

TBC tuberculosis, *ROM* range of motion

Fig. 6. In this case, the previous discrepancy was 6 cm. This postoperative AP pelvic X-ray illustrates that the hip center was not completely restored; however, limb-length discrepancy and pelvic tilt were almost corrected.

The most severe complication affected our last patient, the only one with less than 3 years of follow-up. At the latest follow-up, her Merle d'Aubigné score was 15 points. She had a malpositioned arthrodesis (high on the ilium with flexion greater than 30º) and multiple lateral and anterior scars with severe soft-tissue retraction and multiple invaginations of old sinus tracts. During implant reduction, the femoral artery was stretched and torn. She had to be placed in the supine position and the artery repaired by a vascular surgeon. She also experienced transient common peroneal nerve palsy. Lengthening in this patient was 2 cm, the minimum required to restore the native joint center, and no attempt was made to correct the severe discrepancy over 10 cm.

The type of fusion (extra versus intra-articular), age and time to conversion, the number of previous operations, duration of fusion, diagnosis leading to hip fusion, age at fusion and sex had no association with the clinical outcome following conversion to THA. The Merle d'Aubigné scores were considered excellent, very good, or good for 69% of hips with previous surgical fusions compared with 75% for the hips that had had spontaneous fusions. When maximum flexion was studied, spontaneous fusions had significantly better results than surgical fusions. The three patients younger than 30 years old (fusions for 2–11 years) had higher functional scores than the other patients (>57 years old). A non-significant trend suggested that spinal pain as the main reason for conversion was associated with better results (90%) than knee pain (62%) or pain in the neighboring joints (50% good results).

Discussion

Conversion THA is a technically demanding procedure that is indicated in cases of back pain or functional impairment of other joints, before ipsilateral TKA (mainly if the hip arthrodesis is malpositioned), and in cases of painful nonunion [6, 11, 12].

The aim of the present report is the assessment of the mid-term clinical outcome of patients who underwent conversion at our department over the last 14 years. We also studied the incidence of complications and correlation between patient demographics and characteristics of the fusions with the outcome of the procedure. Nineteen of the 20 cases had functioning implants at the latest follow-up visit. According to the Merle d'Aubigné scale, outcome was considered excellent, very good, or good in 15 cases. Lower back pain was reduced in all patients. All but two patients were satisfied after the conversion. The main complications observed included incomplete removal of bone block, heterotopic ossifications, one dislocation and damage to the femoral artery. The type of fusion, age and time to conversion could not be associated to the clinical outcome following conversion to THA. We observed a significantly higher ROM in patients that had spontaneous fusion.

The limitations of this study include the challenges inherent in a retrospective case series, such as the lack of a control cohort or the absence of a randomization method to avoid potential bias. Finally, patients were asked whether they were satisfied with the outcome of the procedure which is not a validated questionnaire. However, other studies [15] do assess patient satisfaction in this way and the answers were of interest to us.

The survival and functional outcome of THA over previous arthrodesis has been reported to be more similar to that of revision THA than that of primary THA [7, 11, 12]. In our series, 19 out of 21 cases (90.5%) had functioning implants at the most recent follow-up visit. Continuous improvement for 2–3 years after THA was common in previous reports and also in ours [3, 5, 7, 11–13]. This may reflect a beneficial and continuous effect of THA on the abductor muscles and neighboring joints (spine, knee) after years or decades with an abnormal gait. Functional status was rated as poor or fair in 28.5% (6 out of 21) of our cases, which is clearly poorer than that of primary THA [4]. Spinal pain, as the main reason for conversion, may be associated with better results than knee pain or pain in the neighboring joints. This may be because pelvic tilt improved or was corrected in 11 out of 17 cases, despite severe scoliosis and spinal degenerative changes, thus revealing that functional deformity is always present with uncorrected co-existing severe limb-length discrepancies. However, further studies considering this hypothesis are required. It is crucial for patient satisfaction to establish real expectations, as in any other elective procedure [11, 12]. In our limited series, patient satisfaction was not related to residual limp. We consider that the surgeon must inform the patient that clinical and subjective improvement has to be balanced against residual limp, need for crutches, or the possibility of TKA in cases with severe osteoarthritis of the knee.

Postoperative complication rate reported by other investigators varies widely from 11% to 54% whereas the noted overall implant survival ranges from 74% to 96% at 10 years with revision surgery as the endpoint [5, 7, 11,

12, 14]. We encountered a relatively high complication rate (38%) and a low revision surgery rate (9'5%) at a mean follow-up of 8 years when compared to the reported literature. Limb-length discrepancy of up to 3–5 cm can be corrected without complications, depending on the age the arthrodesis was performed, soft-tissue retraction, and previous injuries [2, 6, 9]. Our worst complication, a combined neurovascular injury, was observed in a patient with multiple lateral and anterior retracted scars and invaginations of old sinus tracts.

Age has been postulated as one of the main prognostic factors after THA and may be a more important predictor than time from fusion to THA, which does not seem to be a prognostic factor in the literature [14]. Our three patients younger than 30 years had higher functional scores than patients older than 57 years. Two of them, underwent revision 2 and 11 years after conversion, and their hips remained stable and pain-free. Their excellent functional status may be explained by their age, better overall physical condition, and unaffected neighboring joints. The relevance of factors such as spontaneous versus postoperative ankylosis, the number of previous operations, and the status of the gluteus muscles, remain, to some extent, open to debate [5, 11, 12]. Conversion of spontaneous intra-articular fusions may be less complicated and more successful than surgical fusions [8], although revision rates are similar in the long-term. In our series, patients with surgical ankylosis showed greater improvement than those with spontaneous ankylosis, although the differences were not significant. The status of the abductor muscles may also be a prognostic factor for functional outcome [7] but not for patient satisfaction. Before surgery, the status of these muscles cannot be accurately determined using electromyography or computed tomography [1], and some authors have proposed that takedown should depend on the intra-operative status of the abductor muscles [1, 5]. We do not consider this a realistic approach in our clinical practice. Surgical fusions may jeopardize the abductor muscles more than spontaneous ones. Since the nature of arthrodesis is not described in detail in the literature, comparison is very difficult. Most of our patients had undergone arthrodesis with a combination of anterior approaches and fixation from the lateral side of the femur with Thornton nails and screws without plating the superior iliac bone. Although fixation is less solid with this technique, damage to the abductor muscles is greatly reduced, thus explaining, at least in part, why some surgical fusions in our series were as good as spontaneous ones. Therefore, the fusion technique may also be considered a prognostic factor. This finding could also explain our relatively low frequency of patients with relevant limping. In most of our series, the abductors were present—although atrophic—and responded well to a continuous program of strengthening and rehabilitation.

In conclusion, conversion THA is a challenging but successful procedure according to the mid-term clinical outcome and the low complication rate observed. Since the relative influence of prognostic factors is to some extent controversial, it is crucial for patient satisfaction to establish real expectations.

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Disclosures

Conflict of Interest: Manuel Villanueva, MD, PhD; Francisco Borja Sobrón, MD; Javier Parra, MD; Jose Manuel Rojo Manaute MD, PhD; Francisco Chana, MD PhD; Javier Vaquero Martín, MD, PhD have declared that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was obtained from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

References

1. Amstutz HC, Sakai DN. Total joint replacement for ankylosed hips. Indications, technique, and preliminary results. *J Bone Joint Surg Am*. 1975;57:619-25.
2. Barrack RL. Neurovascular injury. Avoiding catastrophe. *J Arthroplasty*. 2004;19(S1):104-107.
3. Callaghan JJ, Brand RA, Pedersen DR. Hip Arthrodesis. A long-term follow-up. *J Bone Joint Surg Am*. 1985;1328–35
4. Fernandez-Fairen M, Murcia-Mazón A, Torres A, Querales V, Murcia A Jr. Is total hip arthroplasty after hip arthrodesis as good as primary arthroplasty? *Clin Orthop Relat Res*. 2011;469(7):1971-83.
5. Hamadouche M, Kerboull L, Meunier A, Courpied JP, Kerboull M. Total hip arthroplasty for the treatment of ankylosed hips: a five to twenty-one year follow-up study. *J Bone Joint Surg Am*. 2001;83:992-998.
6. Idulhaq M, Park KS, Diwanji SR, Yoon TR, Wie JS. Total hip arthroplasty for treatment of fused hip with 90° flexion deformity. *J Arthroplasty*. 2010;25:498-502.
7. Joshi AB, Markovic L, Hardinge K, Murphy JC. Conversion of a fused hip to total hip arthroplasty. *J Bone Joint Surg Am*. 2002;84:1335-1341.
8. Kilgus DJ, Amstutz HC, Wolgin MA, Dorey FJ. Joint replacement for ankylosed hips. *J Bone Joint Surg Am*. 1990;72:45-54.
9. Kim YH, Oh SH, Kim JS, Lee SH. Total hip arthroplasty for the treatment of osseous ankylosed hips. *Clin Orthop Relat Res*. 2003;414:136-48.
10. Merle D'AR. Functional results of arthroplasty of the hip. *Acta Orthop Belg*. 1953;19(3):81-103.
11. Peterson ED, Altenburg A, Nemanich JP, Cabanela ME. Hip arthroplasty after previous arthrodesis. *Clin Orthop Relat Res*. 2009;467(11):2880-5.
12. Richards CJ, Duncan CP. Conversion of hip arthrodesis to total hip arthroplasty: survivorship and clinical outcome. *J Arthroplasty*. 2010 Mar 24. [Epub ahead of print]
13. Roberts CS, Fetto JF. Functional outcome of hip fusion in the young patient. Follow-up study of 10 patients. *J Arthroplasty*. 1990;5:89-96.
14. Strathy GM, Fitzgerald RH. Total hip arthroplasty in the ankylosed hip. A ten year follow-up. *J Bone Joint Surg Am*. 1988;70:963-6.
15. Williams AA, Witten DM. The benefits of implant removal from the foot and ankle. *J Bone Joint Surg Am*. 2012;94:1316-20.