Articulated Hip Distraction

A Treatment Option for Femoral Head Avascular Necrosis in Adolescence

Jaime A. Gomez, MD,† Hiroko Matsumoto, MA,*†‡ David P. Roye, Jr, MD,*†*
Michael G. Vitale, MD, MPH,†‡ Joshua E. Hyman, MD,*† Harold J.P. van Bosse, MD,§*
Salih Marangoz, MD,§ Debra A. Sala, MS, PT,§ Matthew I. Stein, BS,§ and David S. Feldman, MD§

Purpose: To describe the clinical outcomes of adolescent patients treated with articulated hip distraction (AHD) for avascular necrosis (AVN) of the femoral head. Outcomes were examined in order to better understand the usefulness of and indications for performing hip arthrodiastasis in this patient population.

Methods: Retrospective review was performed on 31 hips with femoral head AVN treated with AHD. Mean age at treatment was 14.7 years. Preoperative and follow-up pain and physical limitations, as well as follow-up range of motion, were assessed.

Results: Follow-up assessment was obtained at 18.7 years. Time of follow-up was 57.4 months after distraction. The etiologies of AVN were the following: 10 slipped capital femoral epiphysis (SCFE), 5 idiopathic AVN, 3 with hip dysplasia, and 12 others. There was a significant difference in pain preoperatively and postoperatively ($P < 0.001$), most patients (78.6%, n = 22) had less pain after the treatment. Multivariate regression model demonstrated that patients with SCFE were likely to have less improvement in pain than patients with other etiologies (odds ratio, 22.7; $P = 0.035$). All patients had activity limitations before the treatment; at the postoperative assessment, half of our patients (n = 14) reported no limitations in their regular daily activities. Eight patients had minor complications with the fixator. At follow-up, 5 patients (17.2%) converted to total hip replacement or arthrodesis. Survival rates were 90.6% at 5 years, 77.7% at 10 years, and 38.8% at 15 years.

Conclusions: Hip distraction arthroplasty in adolescent patients with symptomatic AVN reduces the amount of pain and limitation in daily activities at a follow-up of 4.7 years. Arthrodiastasis is not the final solution to AVN. With longer follow-up, patient's symptoms increases. Patients with AVN secondary to SCFE do not seem to benefit from this procedure as much as other patients do. Articulated hip distraction is a safe and appropriate procedure to perform in these patients. The procedure might be able to delay definitive surgical procedures at an early age, restoring function and improving the patient's quality of life.

From the *Division of Pediatric Orthopaedics, Department of Orthopaedic Surgery, Columbia University, College of Physicians and Surgeons; †Pediatric Orthopaedic Surgery, Morgan Stanley Children's Hospital of New York-Presbyterian, Columbia University Medical Center; ‡International Center for Health Outcomes and Innovation Research and the Joseph L. Mailman School of Public Health, Columbia University; and §Division of Pediatric Orthopaedics, NYU Hospital for Joint Diseases, New York, NY.

Reprints: Jaime A. Gomez, MD, 3959 Broadway, 8th Flr N, New York, NY 10032. E-mail: jaimeg302@gmail.com.

Key Words: distraction arthroplasty, articulated hip distraction, hip arthrodiastasis, femoral head osteonecrosis, avascular necrosis of the femoral head

(*J Pediatr Orthop* 2009;29:163–169)

The management of avascular necrosis (AVN) of the femoral head in children has no "gold standard," and debate still exists over the best treatment. Based on Salter's[1–3] concept of regeneration of articular cartilage, using continuous passive motion, articulated distraction prevents contact between the articular surfaces, thus breaking the cycle of trauma subchondral fractures and ischemic episodes. This allows the joint to heal and prevents joint collapse and destruction.

Canadell et al[4] and Aldegheri et al[5] reported treating the sequelae of Perthes, epiphysiolisis, DDH, fracture of femoral neck, ostheoarthrosis, and chondrolysis with articulated arthrodiastasis. They reported outcomes that included pain reduction, spherical congruency on x-rays, and return to normal activity in some patients. Thacker et al[6] recently reported good results in 11 children that they treated with a 4.8 year follow up. Although 4 patients had complications, they concluded that arthrodiastasis is an effective treatment and an alternative to hip fusion in this difficult group of patients.

Articulated hip distraction (AHD) can be beneficial for patients because it acts by decreasing the joint reaction force. Muscle forces are neutralized, and weight-bearing forces flow through the fixator instead of the joint. This neutralization of muscle forces is obtained with the external fixator, which distracts between the pelvis and the proximal femur, allowing separation of the articular surfaces. Decrease in contact allowed by the arthrodiastasis, together with the range of movement that is allowed for by the hinge, decreases mechanical stress, may restore normal vascularity of the synovial tissue, and may enhance the repair mechanisms that aid cartilage regeneration.[2,7] The procedure will allow breaking the vicious circle of osteonecrosis of trauma, subchondral fracture, ischemic episode, and revascularization, allowing cartilage regeneration. The goal of the treatment applied at our institution was to improve pain allowing patient's return to normal activity. This procedure was designed to postpone conversion to a definitive surgical procedure such as arthrodesis or total hip replacement (THR).[8–10] The purpose of this current study is to describe a cohort of adolescent

FIGURE 1. Preoperative AP pelvis x-ray, showing AVN changes of the right femoral head.

patients with end stage hip disease of various etiologies who were treated with AHD.

METHODS

Participants

After Institutional Review Board approval, 28 patients and 30 hip joints with diagnosis of AVN of the femoral head that were treated between March 1990 and December 2005 with distraction arthroplasty were identified and enrolled in this retrospective cohort study. All patients were treated at 1 of 2 first level institutions by 1 of 5 pediatric orthopaedic surgeons that frequently deal with pediatric and young adult hip pathology. The indications for applying the treatment to these patients were continuous hip pain and inability to walk more than 100 yards, all of the patients had advanced femoral head deformity (Fig. 1). Twenty males (21 hip joints) and 8 females (9 hips) were identified. Patients were not excluded based on etiology, the causes of AVN (Table 1): slipped capital femoral epiphysis (SCFE) in 10 (33.3%) hips; idiopathic AVN 5 (16.7%); dysplasia of the hip 3 (10.0%); femoral neck fracture in 2 (6.7%); septic arthritis 2 (6.7%); sickle cell disease 2 (6.7%); systemic lupus erythematous 2 (6.7%); secondary to steroids 1 (3.3%); developmental juvenile rheumatoid arthritis 1 (3.3%); multiple epiphyseal dysplasia in 1 (3.3%); Gaucher disease 1 (3.3%). A group of patients for which contact information was available was invited to a follow-up visit where a physical examination and anteroposterior (AP) pelvis x-rays were obtained. For the patients that were not reachable, hospital chart information from their latest follow-up visit with their treating orthopaedic surgeon was obtained. Thirty-one hips were followed, 2 were lost because they never returned to follow-up or because hospital charts were missing. The 2 patients

TABLE 1. Patients Treated With Distraction Arthroplasty, Diagnosis, and Related Procedures

1	Femoral neck fracture	L-distraction arthroplasty/L-femoral valgus osteotomy
2	SCFE	SCFE pinning/R-distraction arthroplasty/femoral resurfacing
3	Femoral neck fracture	Fracture fixation with DHS/R-distraction arthroplasty
4	Idiopathic AVN	R-distraction arthroplasty
5	SCFE	Bilateral SCFE pinning/L-distraction arthroplasty
6	SCFE	SCFE pinning/distraction arthroplasty/femoral valgus osteotomy
7	Developmental dysplasia of the hip	Bilateral valgus osteotomies, R-distraction arthroplasty
8	Developmental dysplasia of the hip	Bilateral valgus osteotomies, R-distraction arthroplasty
9	Secondary to steroids	R-distraction arthroplasty/THR
10	Septic arthritis	R-distraction arthroplasty/R-girdlestone/R-chiari/R-removal of intermediate hip screw
11	SCFE	B-SCFE pinning/R-chiari; R-distraction arthroplasty
12	Idiopathic AVN	Distraction arthroplasty, fascia lata release/THR
13	Septic arthritis	R-valgus osteotomy/R-femoral lengthening/R-distraction arthroplasty/R-femur extension—abduction osteotomies
14	SCFE	R-SCFE pinning/R-distraction arthroplasty/R-femoral valgus osteotomy/THR
15	Sickle cell disease	Distraction arthroplasty
16	SCFE	SCFE pinning/removal of the screw and L hip pinning/distraction arthroplasty
17	Sickle cell disease	Distraction arthroplasty
18	Juvenile rheumatoid arthritis	Soft tissue release R hip/distraction arthroplasty
19	Multiple epiphyseal dysplasia	Distraction arthroplasty
20	Gaucher disease	Distraction arthroplasty, adductor tenotomy
21	Idiopathic AVN	Distraction arthroplasty
22	Developmental dysplasia of the hip	R Salter and VDRO/Removal of Salter pin and hip plate, R-distraction arthroplasty
23	SCFE	SCFE pinning/replacement of cannulated Richards K-wire hip/distraction arthroplasty
24	Idiopathic AVN	Distraction arthroplasty
25	Idiopathic AVN	L Salter/ROH/VDRO L hip; ROH, L-distraction arthroplasty/femoral valgus osteotomy/hip arthrodesis
26	Systemic lupus erythematosus	Distraction arthroplasty
27	Systemic lupus erythematosus	Distraction arthroplasty
28	SCFE	Bilateral SCFE pinning/base of femoral neck osteotomy/distraction arthroplasty/L valgus osteotomy
29	SCFE	SCFE pinning; removal of R hip screw, distraction arthroplasty
30	SCFE	SCFE pinning/distraction arthroplasty/R-chiari/R-femoral lengthening
31	SCFE	SCFE pinning/VDRO/distraction arthroplasty

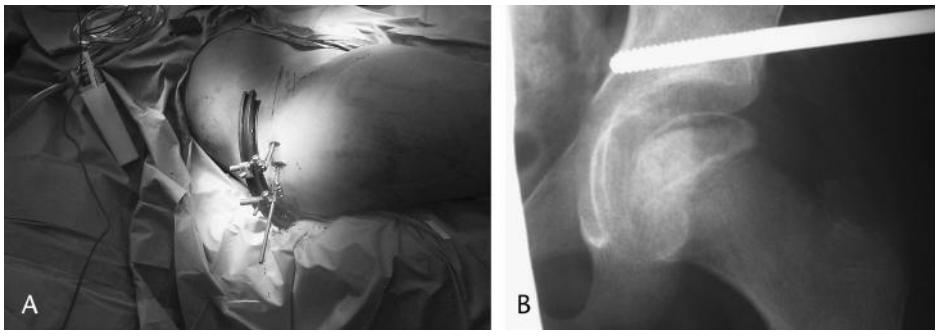

FIGURE 2. A, Intraoperative picture demonstrating positioning of 2 supra acetabular Schanz pins. B, AP left hip magnified x-ray demonstrating positioning of a supra acetabular Schanz pin.

excluded from the analysis underwent hip distraction at age 17, 1 male with diagnosis of idiopathic AVN and the other patient was a female that presented with septic arthritis of the hip, which subsequently was complicated with osteonecrosis of the femoral head. The average age at final evaluation was 18.7 ± 5.1 years, ranging from 12 to 32 years. At the time of the follow-up chart review, 5 patients (17.9%) had converted to a definitive procedure; 3 patients underwent THR at ages 24, 28, and 22 years. One patient underwent hip resurfacing at age 17 years and another patient received a hip arthrodesis at age 13 years. The average number of surgical interventions related to the diseased hip, including the distraction arthroplasty, was 2.3 (range, 1–5 procedures). Other than distraction arthroplasty, the procedures done were femoral varus, innominate, and shelf osteotomies among others (Table 1).

Physical Assessments

The levels of pain and activity limitation were evaluated before and after the treatment. The amount of pain was assessed using a 3-point Likert scale, (1) mild or no pain; (2) moderate pain; and (3) severe pain. The categories were assigned according to the physician's assessment preoperatively and at the time of last follow-up. The physical limitation caused by this condition was measured as a dichotomous variable classifying each patient preoperatively and postoperatively as "limited" or "not limited in regular activities." For patients who had already received a THR or an arthrodesis, the preoperative assessment performed before the definitive surgery was used as the follow-up evaluation for this review. Range of motion (ROM) of the diseased hips was measured for the patients that came to the last follow-up visit and was obtained from the last visit on the charts for the nonresponding subjects. Six goniometric measurements were obtained by the treating physician using a single measurement technique. Flexion, extension, abduction, adduction, internal rotation, and external rotation measures were obtained. These measurements where not obtained preoperatively, although efforts to obtain them were pursued, clinical notes were not consistent, and these parameters where not always recorded. Range of motion measurements were then compared with those of healthy children in an effort to demonstrate the patient's situation at follow-up. The mean time of follow up from the initial distraction arthroplasty to the last assessment was 57.4 months, ranging from 11 to 186 months.

Surgical Procedure

All patients had a similar surgical procedure at a mean age of 14.7 ± 2.5 (range, 9–19) years. The procedure was conducted while the patient was under general anesthesia in supine position on the operating room table following previous antibiotic administration. If neutral alignment of the hip could not be obtained, necessary soft tissue releases were performed, including adductor lengthening and hip flexor lengthening. Two or 3 supra acetabular half pins were placed under x-ray control (Figs. 2A, B), and 2 additional half pins were inserted between the medial and lateral walls of the ilium. These pins together comprise the proximal montage

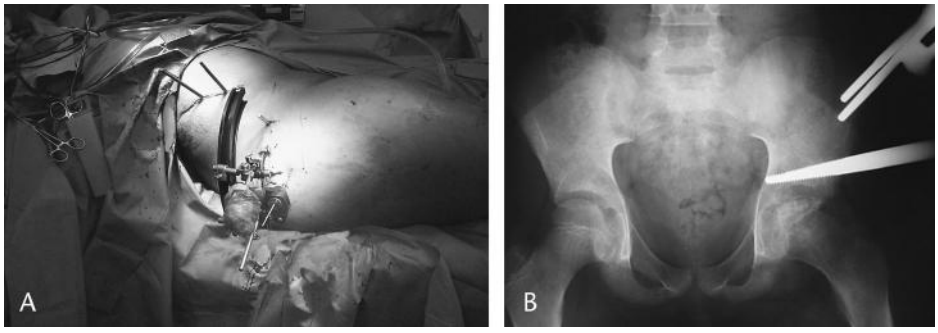

FIGURE 3. A, Intraoperative picture demonstrating Schanz pins inserted between the medial and lateral walls of the ilium. B, AP left hip x-ray showing the proximal montage.

FIGURE 4. A, Intraoperative picture demonstrating the articulated external fixator in position. B, AP pelvis x-ray of external fixator positioned.

(Figs. 3A, B). Two or 3 half pins were placed in a vertical montage in the shaft of the femur. The joint was fixed using an articulated external fixator (EBI/BIOMET Hinged External Fixator was used; Figs. 4A, B). Care was taken to allow the center of rotation of the femoral head to coincide exactly with the hinge of the fixator. The mean time that the fixator remained on the hip was 17.07 ± 6.0 weeks (7 to 28 weeks). The alignment of the center of rotation is a crucial part of the procedure because if not well done, movement will be limited and perhaps painful, loosening of the pins is more likely, and the overall goals of the procedure will not be met (Fig. 5).

Statistical Analysis

Descriptive analyses were performed to demonstrate characteristics of patients, surgical procedures, and complications. χ^2 analyses and paired samples *t* tests were conducted to compare preoperative and postoperative outcomes. Regression analyses were conducted to identify predictors of changes in pain and activity level and postoperative ranges of motion. All statistical tests were 2-tailed, and a $P < 0.05$ was considered to be significant. A Kaplan-Meier survivorship curve was generated with failure defined as the performance of definitive surgery. All statistical analyses were conducted using SPSS version 14.0.

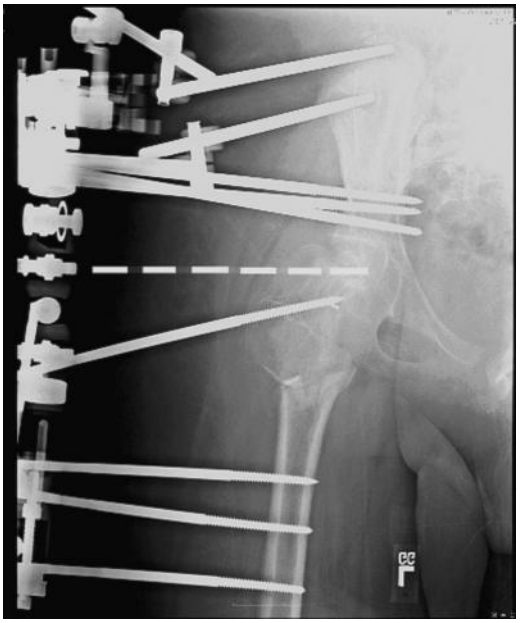

FIGURE 5. A, AP pelvis x-ray demonstrating appropriate alignment of the femoral head center of rotation.

RESULTS

Pain

There was a significant difference in pain preoperatively and postoperatively ($P < 0.001$). All patients had moderate to severe pain preoperatively. Approximately two thirds of the patients had severe pain (n = 18), and one third of the patients (n = 10) had moderate pain. The evaluation of postoperative pain showed that most of patients (67.9%, n = 19) had no or mild pain, 14.2% (n = 4) reported moderate pain, and 17.9% (n = 5) had severe pain. Most patients (78.6%, n = 22) had less pain after the treatment. Only 2 patients (7.1%) had the same amount of pain and 4 patients (14.3%) (3 SCFE, 1 developmental dysplasia of the hip) reported that their pain got worse postoperatively (Table 2).

Patients who had the same or more pain at follow up than at the preoperative assessment were grouped together into patients with no improvement. Univariate analysis demonstrated that the age at the postoperative assessment in the patients who had improvement in pain (17.5 ± 4.1) was significantly lower ($P = 0.017$) than the patients who did

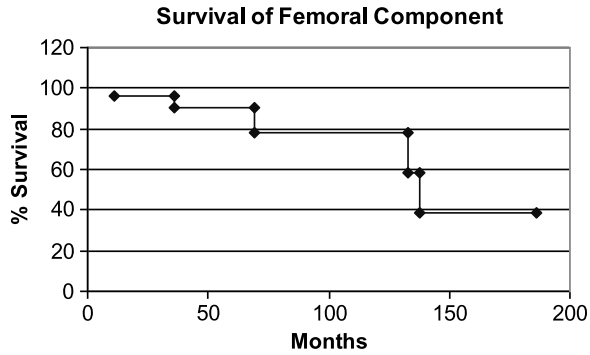

FIGURE 6. Kaplan-Meier Survival Analysis of the femoral component.

TABLE 2. Change in Pain Scale

		Post-Op Pain Prior Definitive Surgery			Total
		Mild or No Pain	Moderate Pain	Severe Pain	
Preoperative Pain	moderate pain	5	1	4	10
	severe pain	14	3	1	18
Total		19	4	5	28

notobtain improvement (23.0 ± 6.5). There was significant difference in pain outcomes between patients who had a SCFE as an etiology for their AVN and those who did not (P = 0.013). Among patients who had SCFE, 22.7% had improvement in pain, whereas 83.3% of patients with other diagnoses demonstrated improvement. There was a trend toward significant difference in length of time with the external fixator between the 2 cohorts (P = 0.068). Patients who obtained improvement in pain had longer length of time with the fixator (18.3 ± 5.8 weeks) than patients who had no improvement (12.8 ± 5.6 weeks). In addition, the number of hip-related surgeries in the patients who improved in pain (2.0 ± 1.1) had a trend toward significantly lower (P = 0.060) than the patients who had no improvement (3.0 ± 0.9). There were no significant differences between the 2 pain outcome groups based on sex, diagnosis, or age at initial surgery.

Multivariate analysis demonstrated that pain improvement was significantly lower in patients with SCFE (odds ratio: 22.7; P = 0.035). Age at postoperative assessment had a trend toward significance (odds ratio, 1.3; P = 0.077) in predicting likelihood of improvement in pain Negelkerke R^2 indicated that this model explained 54.7% of the variance of likelihood of improvement in pain (Table 3).

Activity Limitations

All patients had activity limitations before the treatment. At the postoperative assessment, half of our patients (n = 14) reported no limitations in their regular daily life activities and returned to their normal activity level, whereas the other half of our patients (n = 14) still had limitations in their regular activities such as walking moderate distances (more than 100 yards).

There were significant differences in activity limitation outcomes based on sex (P = 0.033). Approximately two thirds of male patients (N = 13) improved in activity level, whereas only one patient (12.5%) among the females showed improvement. In addition, there was a significant difference in changes in activity limitation between patients who had SCFE and those who did not. Among patients who had SCFE, 20.0% improved in their activities after the treatment, whereas 66.7% improved in activity limitation among patients without SCFE. There was also a trend toward significant difference in activity limitation between patients who had idiopathic AVN and patients without idiopathic AVN (P = 0.098). All idiopathic AVN patients improved in their activity levels after the treatment, whereas less than half (41.7%) of nonidiopathic AVN patients had improvement in their activity levels. There were no significant difference between the 2 outcome cohorts based on ages at initial surgery and at postoperative assessment, length of time with the external fixator, and the number of hip related surgeries.

TABLE 3. Multivariate Regression Model Predicting Improvement in Pain

Predictors	Odds Ratio	95% Confidence Interval	P
SCFE	22.74	1.24–415.65	0.035
Age at postoperative visit	1.30	0.97–1.74	0.077

Negelkerke R^2 = 0.547.

TABLE 4. Multivariate Regression Model Predicting Improvement in Activity Level

Predictors	Odds Ratio	95% Confidence Interval	P
Sex	14.0	1.2–166.7	0.036
SCFE	8.5	1.1–66.7	0.039

Negelkerke R^2 = 0.460.

A multivariate analysis demonstrated that sex (odds ratio, 14.0; P = 0.036) and whether patients had SCFE or not (odds ratio: 8.5; P = 0.039) maintained their significance in predicting likelihood of improvement in activity level. Negelkerke R^2 indicated that this model explained 46.0% of the variance of likelihood of improvement in activity level (Table 4).

Range of Motion

Range of motion at the postoperative assessment is presented in Table 5. Because of the lack of preoperative assessment, the researchers were unable to analyze changes in ROM before and after the treatment.

Complications

Most patients (71.4%) did not experience complications, whereas 28.6% (n = 8) encountered complications, which did not result in clinically significant sequelae. Six patients (21.4%) had pin site infections that were treated with antibiotics and appropriate dressing changes. One patient (3.6%) presented with a significant leg length discrepancy after the treatment and another patient (3.6%) had increasing pain with the fixator that was controlled with oral analgesics.

Survivorship Analysis

A Kaplan-Meier survivorship analysis, with failure defined as the performance of definitive surgery, is given

TABLE 5. Follow-up ROM Descriptive Statistics

	N	Norm	Minimum	Maximum	Mean	SD
Hip Flexion	24	120.0	25.00	110.00	80.65	26.60
Hip Extension	22	20.0	.00	40.00	4.76	10.18
Hip Internal Rotation	14	42.5	.00	50.00	10.00	13.09
Hip External Rotation	14	32.5	5.00	45.00	25.00	14.39
Hip Abduction	12	45.0	0.00	35.00	20.77	10.58
Hip Adduction	8	20.0	0.00	40.00	18.00	11.60

in Figure 6. Survival rates were 90.6% at 5 years, 77.7% at 10 years, and 38.8% at 15 years.

In comparing the survivors to the failed group, given the small sample size, there was a significant difference in preoperative (before hip distraction) pain ($P = 0.041$). More than 70% of patients had severe pain in the survivor group, whereas only 20% had severe pain in the failed group. There were no significant difference between the 2 cohorts with regard to age at surgery, sex, diagnosis, and preoperative activity limitations.

DISCUSSION

Adolescents with AVN and collapse of the hip present a difficult problem to manage. Articulated hip distraction has been used in these difficult circumstances in the last 4 decades, but evidence of efficacy is scant.[11] The literature contains primarily multiple case reports with small sample sizes and relatively short follow-up times. This 2-institution review attempts to examine the survivorship of this treatment modality. The average follow-up of nearly 5 years is the longest in the literature and gives some perspective. We have followed up 5 of 28 patients (17.9%) of these hips to "failure" that is conversion to THR, resurfacing or arthrodesis which occurred at a mean follow-up of 6.45 years after the distraction procedure. Importantly, 64.3% of patients had severe pain preoperatively, 17.9% had severe pain at follow-up, and 67.9% had mild or no pain at the last follow-up, again keeping in mind that the mean follow-up was 55 months.

Our result demonstrated a lack of improvement in pain among the group of patients whose osteonecrosis etiology was an SCFE. We hypothesize that an SCFE represents a mechanical disruption as well as AVN; however, the position of the femoral head in AVN may make distraction ineffective. The other etiologies of AVN in this case series have different mechanisms that do not change the position of the femoral head with the AVN.

We also found that pain at the time of follow-up was significantly higher in older patients. This is a reasonable finding because distraction arthroplasty is not meant to completely treat the problem. It allows us to postpone the definitive procedure such as hip replacement and arthrodesis. Therefore, we expect patients to feel more pain and limitation in their activities as they get older which ultimately leads them to definitive procedures.

Although it did not remain significant in the multivariate regression model, it is important to note that patients with fewer surgical procedures and/or patients with longer time with the fixator presented with less pain at the time of follow-up. It is possible that the number of surgeries represents the severity of the condition; therefore, patients who had more surgeries reported more pain. The cumulative trauma and scarring of multiple procedures may also contribute. It is also reasonable to postulate that the longer the length of the time in the fixator the less pain the patients reported. It is possible that longer distraction period allow more joint regeneration. Although these 2 findings are interesting, the significance did not stand after performing the multivariate analysis.

After management with ADH survival rates were 90.6% at 5 years, 77.7% at 10 years, and 38.8% at 15 years. Other types of treatment for this severe pathology have shown different results. With core decompression, a survival of 65% was found at follow up ranging from 12 months to 12 years.[12] When intertrochanteric flexion osteotomy was attempted, 88% survival was found at 5 years and 76% at 10 years[13] and with valgus osteotomies 76% at 4 years.[14] When patients were treated with rotational osteotomies, authors found a 50% to 66% survival through a range of 5 to 10 years.[17,18] With femoral head grafting for hips classified as Ficat and Arlet (F&A) III and IV survival was found to be 77% and 61%, respectively, at 5 years.[18] Our survival numbers show adequate survival at 5 and 10 years, which are comparable with other treatment modalities. At 15 years of follow-up, survival percentages drop with ADH, but longer follow-ups for survival with other procedures need to be evaluated to be compared with our survival rate. The rare appearance of this severe type of pathology has not allowed for a larger sample size, the low survival at 15 years of follow-up could be an effect of the small sample size. In addition, more than 70% of patients had severe preoperative pain in the survivor group, whereas only 20% had severe pain in the failed group. We believe there is no clinical significance in this finding.

A significant limitation of this report is the lack of a control group. We assessed the efficacy of the intervention without concurrent data on natural history. This cohort of patients was treated with arthrodiastasis on the basis of symptoms. Treatment was not based on x-ray appearance or any accepted classification of AVN, however, most of our patients had significant collapse of the femoral head and thus hip distraction was performed as a salvage procedure.

The literature does provide some comparisons that allow a general assessment of this technique. Mont et al[12] demonstrated that core decompression has been used to improve the outcome in AVN. A recent metaanalysis on 1206 hips treated with this method showed a conversion rate, meaning THR, resurfacing procedures, or arthrodesis of 35% in stage II (F&A) at a follow-up ranging from 12 to 144 months. Our patients deformity was certainly worse but the conversion rate was lower, the patients included in our study all had F&A classification IV or V with clear collapse of the femoral head.

An interesting group of patients that can be compared with our distraction arthroplasty cohort is the one treated with femoral osteotomies. Drescher et al[13] studied 65 hips and found conversion rates of 12% at 5 years and 24% at 10 years of follow-up after intertrochanteric flexion osteotomy for stages III and IV hips. Simank et al[14] evaluated 83 hips with the same procedure and similarly found 17% conversion at 4 years for F&A stages II, IV, and V. Varus and valgus osteotomies have shown conversion rates of 27% and 24%, respectively, in similar studies.[15,16] Rotational osteotomies report conversions between 33% and 50% for stages III and IV at follow-ups of 60 months to 10 years.[17,18] The conversion rate in this study was substantially lower that that for rotational and angular osteotomies.

Grafting the femoral head with either vascularized or nonvascularized bone graft has been performed to prevent femoral head collapse. Outcomes appear bleak when performed in the later stages of the osteonecrosis. Urbaniak et al[19] reported a 23% and a 39% of conversion rates in stages III

and IV, respectively, at 5 years of follow-up, and other studies have shown similar outcomes.[20–22] Hip arthrodiastasis demonstrated a 13.8% conversion rate at 52.3 months, which makes it similar to all the other treatments mentioned previously for the treatment of late stages of necrosis.

This study confirms safety and implies efficacy. Complications were those associated with external fixators and with the osteotomies used to treat proximal femoral deformity. None of the reported complications had lasting impact on patient outcome.

This review demonstrated that hip distraction arthroplasty was safe, able to improve pain, able to improve function, and was likely to delay the need for total hip or similar procedures in young patients.

REFERENCES

1. Salter RB. The biologic concept of continuous passive motion of synovial joints. The first 18 years of basic research and its clinical application. *Clin Orthop Relat Res*. 1989;242:12–25.
2. Salter RB, Simmonds DF, Malcolm BW, et al. The biological effect of continuous passive motion on the healing of full-thickness defects in articular cartilage. An experimental investigation in the rabbit. *J Bone Joint Surg Am*. 1980;62:1232–1251.
3. Salter RB. Continuous passive motion: from origination to research to clinical applications. *J Rheumatol*. 2004;31:2104–2105.
4. Canadell J, Gonzales F, Barrios RH, et al. Arthrodiastasis for stiff hips in young patients. *Int Orthop*. 1993;17:254–258.
5. Aldegheri R, Trivella G, Saleh M. Articulated distraction of the hip. Conservative surgery for arthritis in young patients. *Clin Orthop Relat Res*. 1994:94–101.
6. Thacker MM, Feldman DS, Madan SS, et al. Hinged distraction of the adolescent arthritic hip. *J Pediatr Orthop*. 2005;25:178–182.
7. van Valburg AA, van Roermund PM, Marijnissen AC, et al. Joint distraction in treatment of osteoarthritis (II): effects on cartilage in a canine model. *Osteoarthritis Cartilage*. 2000;8:1–8.
8. Sponseller PD, McBeath AA, Perpich M. Hip arthrodesis in young patients. A long-term follow-up study. *J Bone Joint Surg Am*. 1984;66:853–859.
9. Torchia ME, Klassen RA, Bianco AJ. Total hip arthroplasty with cement in patients less than twenty years old. Long-term results. *J Bone Joint Surg Am*. 1996;78:995–1003.
10. Sharkey PF, Austin MS, Hozack W. Total hip arthroplasty in the young patient. *Instr Course Lect*. 2006;55:173–176.
11. Kocaoglu M, Kilicoglu OI, Goksan SB, et al. Ilizarov fixator for treatment of Legg-Calve-Perthes disease. *J Pediatr Orthop B*. 1999; 8:276–281.
12. Mont MA, Jones LC, Hungerford DS. Nontraumatic osteonecrosis of the femoral head: ten years later. *J Bone Joint Surg Am*. 2006;88: 1117–1132.
13. Drescher W, Furst M, Hahne HJ, et al. Survival analysis of hips treated with flexion osteotomy for femoral head necrosis. *J Bone Joint Surg Br*. 2003;85:969–974.
14. Simank HG, Brocai DR, Brill C, et al. Comparison of results of core decompression and intertrochanteric osteotomy for nontraumatic osteonecrosis of the femoral head using Cox regression and survivorship analysis. *J Arthroplasty*. 2001;16:790–794.
15. Ito H, Kaneda K, Matsuno T. Osteonecrosis of the femoral head. Simple varus intertrochanteric osteotomy. *J Bone Joint Surg Br*. 1999; 81:969–974.
16. Mont MA, Fairbank AC, Krackow KA, et al. Corrective osteotomy for osteonecrosis of the femoral head. *J Bone Joint Surg Am*. 1996;78: 1032–1038.
17. Hasegawa Y, Sakano S, Iwase T, et al. Pedicle bone grafting versus transtrochanteric rotational osteotomy for avascular necrosis of the femoral head. *J Bone Joint Surg Br*. 2003;85:191–198.
18. Atsumi T, Muraki M, Yoshihara S, et al. Posterior rotational osteotomy for the treatment of femoral head osteonecrosis. *Arch Orthop Trauma Surg*. 1999;119:388–393.
19. Urbaniak JR, Coogan PG, Gunneson EB, et al. Treatment of osteonecrosis of the femoral head with free vascularized fibular grafting. A long-term follow-up study of one hundred and three hips. *J Bone Joint Surg Am*. 1995;77:681–694.
20. Judet H, Gilbert A. Long-term results of free vascularized fibular grafting for femoral head necrosis. *Clin Orthop Relat Res*. 2001:114–119.
21. Kim SY, Kim YG, Kim PT, et al. Vascularized compared with nonvascularized fibular grafts for large osteonecrotic lesions of the femoral head. *J Bone Joint Surg Am*. 2005;87:2012–2018.
22. Aldridge JM 3rd, Urbaniak JR. Avascular necrosis of the femoral head: role of vascularized bone grafts. *Orthop Clin North Am*. 2007; 38:13–22, v.

