Cemented Total Hip Replacement Cable Debris and Acetabular Construct Durability

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Background: Third-body wear can adversely affect the outcome of total hip arthroplasty by causing increased polyethylene wear, osteolysis, and component loosening. We hypothesized that there would be greater generation and migration of metal debris to the bearing surfaces in hips in which cobalt-chromium cables were used to reattach the osteotomized greater trochanter when compared with hips in which stainless steel wires were used.

Methods: Between June 1981 and December 1983, 196 consecutive total hip arthroplasties were performed with use of an Iowa stem and a titanium-backed cemented acetabular component, with cobalt-chromium cable trochanteric reattachment. After nineteen to twenty years of follow-up, the patients were evaluated with regard to the depth of head penetration into the polyethylene (as a surrogate for wear), osteolysis, loosening, and the need for revision. The results were compared with those for a series of 304 total hip arthroplasties that were performed by the same surgeon from January 1984 to December 1985 with use of the same components and the same surgical technique, but with stainless steel wire trochanteric reattachment. The two groups had a comparable nineteen to twenty-year follow-up. All living patients (fifty-nine hips in the cable group and ninety-two hips in the wire group) had minimum ten-year follow-up radiographs.

Results: The polyethylene wear rate was 0.101 mm/yr for the cable group and 0.082 mm/yr for the wire group ($p = 0.039$). For the living patients, the rate of revision of the acetabular component because of aseptic loosening was 37.3% (twenty-two hips) for the cable group and 20.7% (nineteen hips) for the wire group ($p = 0.025$). The rate of acetabular osteolysis was 44% (twenty-six hips) for the cable group and 26% (twenty-four hips) for the wire group ($p = 0.022$). Kaplan-Meier analysis with revision of the acetabular component because of aseptic loosening as the end point demonstrated survival rates of $73.7\% \pm 9\%$ and $83\% \pm 7\%$ for the cable and wire groups, respectively, at twenty years ($p = 0.03$).

Conclusions: Because cable trochanteric attachment led to significantly greater polyethylene wear, osteolysis, acetabular loosening, and acetabular revision, presumably due to third-body metallic debris generation in this cemented total hip replacement construct, surgeons should be aware of the deleterious effects of third-body debris and avoid the use of potential debris generators in the total hip arthroplasty construct. If cable is used and fretting is recognized, especially with intra-articular migration of metallic material or nonunion of the greater trochanter, consideration should be given to cable removal.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

In June 1981, the senior author (R.C.J.) began using braided cable for all total hip arthroplasties to reattach the greater trochanter following greater trochanteric osteotomy in the hopes of decreasing the rate of greater trochanteric nonun-

ion. In January 1984, he resumed using stainless steel wire because he found on early follow-up that the cable was associated with metallic debris produced by fretting and breakage of the cable.

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The hypothesis of the present study was that the metallic particulate debris generated by fretting and breakage of the cobalt-chromium (CoCr) cable would migrate to the bearing surface of the total hip arthroplasty construct and would accelerate bearing surface wear, osteolysis, and component loosening. The purpose of the present study was to evaluate such differences between hips with wire reattachment and hips with cable reattachment of the greater trochanter.

Materials and Methods

The latest follow-up evaluation was conducted with institutional review board approval at a minimum of nineteen to twenty years after the index arthroplasty in both groups and represents the additional follow-up of a subgroup of total hip arthroplasties that were evaluated in a previous study involving a more heterogeneous cohort of cable and wire groups¹.

Between June 1981 and December 1985, the senior author performed 500 sequential, consecutive total hip replacements in 448 patients with use of the same prostheses and technique. A plasma-sprayed, 30-R_a, matte-finished Iowa hip femoral prosthesis (Zimmer, Warsaw, Indiana) was used in all patients. The component was made of cobalt-chromium, had a proximal cobra-shape geometry with rounded corners, and was 140 mm in length to decrease cement strains. A 28-mm-diameter monolithic head and an external collar were included. The prosthesis was available with two neck shaft angles (132° or 140°).

The femoral component articulated with a titanium-metal-backed cup (TiBac; Zimmer) with an outer diameter of 40, 42, 44, 46, 48, 52, 55, 56, or 58 mm. The polyethylene was compression-molded. The cups were monolithic. The polyethylene was cooled with liquid nitrogen by the manufacturer, was allowed to expand within the TiBac shell, and then was sterilized by means of gamma irradiation in air. Simplex-P cement (Howmedica, Rutherford, New Jersey) was used for all arthroplasties.

The operative technique involved a lateral approach, an osteotomy of the greater trochanter, and a complete capsulotomy in 96% of the hips. An anterolateral approach that did not require an osteotomy of the greater trochanter was performed for 4% of the hips. The femoral canal was prepared by removal of all loose cancellous bone and meticulous drying of the canal. A cement plug was placed distally, and a cement gun was used to introduce cement in a retrograde manner with use of so-called contemporary cementing techniques. The acetabulum was reamed as inferiorly and medially as possible with five to eight 5-mm-diameter countersink holes that were placed to help to anchor the cement. The cement was introduced in the doughy stage, and a plunger was used for pressurization.

The greater trochanter was reattached as far laterally as possible. In the first 196 hips, three 1.5-mm CoCr cables or two CoCr cables and one 18-gauge stainless steel wire were used for greater trochanteric reattachment. The cables were constructed of seven smaller braided cables, each consisting of seven CoCr wires per braid, for a total of forty-nine wires.

In the remaining 304 hips, three 18-gauge stainless steel monofilament wires (two vertical, one horizontal) were used to reattach the greater trochanter. Cable reattachment was used

consecutively from June 1981 to December 1983, and wire reattachment was used consecutively from January 1984 to December 1985. Postoperatively, the patients were managed with bed rest on the first day, followed by partial weight-bearing with crutches for six weeks. The patients then progressed to full weight-bearing as tolerated.

We attempted to interview all living patients and the families of the patients who had died. Living patients either returned for clinical and radiographic follow-up or, if they were unable to return, were asked to have radiographs made locally and sent to us for evaluation. An attempt was made to evaluate all living patients in person or by telephone with use of a standard system of terminology for reporting results as described by Johnston et al.²

The average age of the 448 patients (500 hips) at the time of the index arthroplasty was 67.2 years (range, seventeen to ninety years). The average age was 66.2 years for the cable group and 68.2 years for the wire group. One hundred and thirty patients were known to be alive at least nineteen to twenty years postoperatively. The average age at the time of the index arthroplasty was 56.2 years (range, 17.8 to 74.4 years) and 59.4 years (range, 24.8 to 82.0) for the living patients in the cable and wire groups, respectively. Seventy-six percent of the hips in the cable group and 72% of the hips in the wire group underwent total hip arthroplasty for the treatment of symptomatic osteoarthritis. We could not identify a difference between the groups with respect to the demographic variables of sex, age, and diagnosis.

At the time of the most recent follow-up, fifty-two patients (fifty-nine hips; 30.1%) in the cable group were living, 122 patients (136 hips) had died, and one patient (one hip) was lost to follow-up (Table I). Of the patients in the wire group, seventy-eight patients (ninety-two hips; 30.3%) were living (and were willing to participate in the study), 193 patients (210 hips) had died, one patient (one hip) was lost to follow-up, and one patient (one hip) refused to participate. All living patients in both groups had a minimum ten-year anteroposterior radiograph of the pelvis that included the tip of the femoral stem. The mean duration of radiographic follow-up for the living patients in the cable and wire groups was 15.9 years (range, ten to 21.5 years) and 18.3 years (range, ten to 21.8 years), respectively.

In the cable group, the average duration of radiographic follow-up was 10.01 years (range, 5.0 to 20.9 years) for all 196 hips (175 patients) and 17.45 years (range, ten to 23.7 years) for the fifty-nine hips in living patients. In the wire group, the average duration of radiographic follow-up was 10.1 years (range, 5.0 to 21.2 years) for all 304 hips (273 patients) and 18.1 years (10.0 to 23.9 years) for the ninety-two hips in living patients.

Radiographic Evaluation

Radiographs were evaluated by at least three observers (J.J.C., A.J.A., S.S.L.), two of whom reviewed both groups. Agreement was made by consensus. Correction for magnification was obtained by means of standardization of all measurements against the magnification of the measured size of the femoral head as compared with its known size. Osteolysis was defined

TABLE I Comparison of Living Patients in Cable and Wire Groups

	Cable Group	Wire Group	P Value
No. of patients (no. of hips)	52 (59)	78 (92)	
Age at surgery (yr)	56.2	59.4	
Duration of radiographic follow-up* (yr)	15.9	18.3	
Revision for acetabular aseptic loosening (no. of hips)	22 (37.3%)	19 (20.7%)	0.025†
Acetabular radiographic loosening (including hips revised for aseptic loosening) (no. of hips)	32 (54.2%)	28 (30.4%)	0.0035†
Acetabular osteolysis (no. of hips)	26 (44.1%)	24 (26.1%)	0.022†
Proximal femoral osteolysis (zones I and/or VII) (no. of hips)	41 (69.5%)	43 (46.7%)	0.006†
Distal femoral osteolysis (zones II through VI) (no. of hips)	3 (5.1%)	9 (9.8%)	0.3
Linear radiographic wear‡ (mm/yr)	0.101	0.082	0.039§

*The values are given as the mean. †Chi-square test. ‡The values are given as the median. §Wilcoxon rank-sum test.

as any nonlinear radiolucency at the bone-cement interface that was at least 5 mm long and was recorded according to the three acetabular zones described by DeLee and Charnley³ and the seven femoral zones described by Gruen et al.⁴. The position of the femoral stem was determined on the basis of the angle formed between the central axis of the prosthesis and the lateral endosteal cortex.

Loosening of the Acetabular Component

Definite loosening of the acetabular component was defined as migration of the component or any new fracture in the cement mantle; probable loosening, as radiolucency around 100% of the component at the bone-cement interface⁵; and possible loosening, as radiolucency around 50% to 99% of the component at the bone-cement interface⁶. Migration of the acetabular component was evaluated with use of the criteria of Massin et al.⁷. On each radiograph, the vertical distance between the center of the cup and a line joining the two teardrops was measured. The horizontal distance between the center of the cup and a vertical line through the teardrop was also measured. The acetabular component was considered to have migrated if these distances varied by >5 mm between the immediate postoperative radiographs and the radiographs made at the time of the latest follow-up evaluation, after correction for magnification.

Wear

Head penetration was determined with edge-detection techniques developed by Shaver et al.⁸ as a surrogate for linear wear. Wear measurements for both groups were performed by a single observer (T.M.Y.).

Statistical Analysis

The Kaplan-Meier method^{9,10} was used to evaluate survival of the implant with regard to revision, loosening, or both. Survivorship curves with corresponding 95% confidence intervals with accompanying hazard ratios (HR) were generated, with failure defined according to six standard end points: (1) re-

vision of the femoral and/or the acetabular component for any reason, (2) revision of the femoral and/or the acetabular component because of aseptic loosening, (3) revision of the femoral component because of aseptic loosening, (4) radiographic loosening of the femoral component (defined as definite or probable radiographic loosening or revision because of aseptic

Survivorship free of Revision for Any Reason

Fig. 1

Kaplan-Meier survivorship curves comparing the cable and wire groups after nineteen to twenty years of follow-up, with revision for any reason as the end point.

Fig. 2
Kaplan-Meier survivorship curves comparing the cable and wire groups after nineteen to twenty years of follow-up, with revision of the femoral and/or acetabular component because of aseptic loosening as the end point.

loosening), (5) revision of the acetabular component because of aseptic loosening, and (6) radiographic loosening of the acetabular component (defined as definite or probable radiographic loosening or revision because of aseptic loosening).

A Cox proportional-hazard regression analysis using the robust sandwich method¹¹ to estimate the standard error of the regression parameter estimates to account for the correlation of the outcomes for hips from the same patient was performed to compare the six outcome measures between the cable and wire groups.

The chi-square test was used to compare categorical variables. The Wilcoxon rank-sum test was used to compare rates of wear according to categorical variables as these rates are not normally distributed.

Source of Funding

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Results

Revision for Any Reason

In the cable group, the rate of revision of any component because of aseptic loosening was 15.3% (thirty of 196 hips).

Twenty-one hips were revised because of acetabular loosening, none were revised because of femoral loosening, and nine were revised because of both acetabular and femoral loosening. In the wire group, the rate of revision of any component because of aseptic loosening was 8.6% (twenty-six of 304 hips). Nineteen hips were revised because of acetabular loosening, two were revised because of femoral loosening, and five were revised because of both acetabular and femoral loosening. Hence, in the entire patient population, the rate of revision because of aseptic acetabular loosening was 15.3% (thirty of 196 hips) for the cable group and 7.9% (twenty-four of 304 hips) for the wire group. Comparison of Kaplan-Meier survivorship curves revealed a significant difference between groups ($p = 0.03$; Cox regression for comparison of Kaplan-Meier survivorship analysis). For the living patients, all of whom had minimum ten-year radiographs, the rate of revision of the acetabular component because of aseptic loosening was 37.3% (twenty-two hips) for the cable group and 20.7% (nineteen hips) for the wire group ($p = 0.025$).

Additional complications included three revisions because of deep infection in the cable group and one revision because of deep infection in the wire group. In addition, in the wire group, two revisions were performed because of recurrent

Fig. 3
Kaplan-Meier survivorship curves comparing the cable and wire groups after nineteen to twenty years of follow-up, with revision of the femoral component because of aseptic loosening as the end point.

Fig. 4

Kaplan-Meier survivorship curves comparing the cable and wire groups after nineteen to twenty years of follow-up, with radiographic loosening of the femoral component as the end point.

dislocation and two other revisions were performed because of periprosthetic femoral fracture.

Wear

The median linear head penetration rate was 0.101 mm/year (twenty-fifth to seventy-fifth percentile, 0.059 to 0.174) for the cable group, compared with 0.082 mm/year (twenty-fifth to seventy-fifth percentile, 0.051 to 0.143) for the wire group ($p = 0.039$).

Acetabular Aseptic Radiographic Loosening

The rate of acetabular aseptic radiographic loosening for hips in living patients, all of whom had minimum ten-year radiographs, was 54.2% (thirty-two hips) in the cable group and 30.4% (twenty-eight hips) in the wire group ($p = 0.0035$).

Osteolysis

Among living patients, the rate of acetabular expansile osteolysis was 44.1% (twenty-six hips) in the cable group and 26.1% (twenty-four hips) in the wire group ($p = 0.022$), the rate of proximal osteolysis in zones I and/or VII was 69.5% (forty-one hips) in the cable group and 46.7% (forty-three hips) in the wire group ($p = 0.006$), and the rate of distal osteolysis in zones II through VI was 5.1% (three hips) in the cable group and 9.8% (nine hips) in the wire group ($p = 0.3$).

Trochanteric Nonunion

With the numbers available, trochanteric nonunion rates were not significantly different between the groups. The rate of nonunion was 25% (forty-nine of 196) in the cable group and 19% (fifty-four of 279) in the wire group ($p = 0.142$). No significant association was found between linear wear and trochanteric nonunion in the cable group ($p = 0.79$) or the wire group ($p = 0.49$).

Cable Fretting and Breakage

The rate of breakage of the cables on radiographic evaluation was 36.7% (seventy-two of 196 hips). Fretting without breakage occurred in an additional thirty-three hips (16.8%).

Survivorship Analysis

Kaplan-Meier^{9,10} analysis with revision of the femoral and/or acetabular component for any reason as the end point revealed a survival rate of $72.7\% \pm 9\%$ for the cable group and $82\% \pm 6\%$ for the wire group ($HR = 2.18$, $p = 0.026$) (Fig. 1). The survival rate with revision of the femoral and/or acetabular component because of aseptic loosening as the end point was $73.8\% \pm 9\%$ for the cable group and $85\% \pm 6\%$ for the wire group ($HR = 2.17$, $p = 0.034$) (Fig. 2). The survival rate with revision of the femoral component because of aseptic loos-

Fig. 5

Kaplan-Meier survivorship curves comparing the cable and wire groups after nineteen to twenty years of follow-up, with revision of the acetabular component because of aseptic loosening as the end point.

Fig. 6

Kaplan-Meier survivorship curves comparing the cable and wire groups after nineteen to twenty years of follow-up, with radiographic loosening of the acetabular component as the end point.

ening as the end point was $90.6\% \pm 6\%$ for the cable group and $96\% \pm 3\%$ for the wire group ($HR = 8.93$, $p = 0.040$) (Fig. 3). The survival rate with radiographic evidence of loosening of the femoral component (defined as definite or probable radiographic loosening or revision because of aseptic loosening) as the end point was $83.5\% \pm 9\%$ for the cable group and $92\% \pm 5\%$ for the wire group ($HR = 4.23$, $p = 0.033$) (Fig. 4). The survival rate with revision of the acetabular component because of aseptic loosening was $73.7\% \pm 9\%$ for the cable group and $83\% \pm 7\%$ for the wire group ($HR = 2.21$, $p = 0.030$) (Fig. 5). The rate of survival with radiographic evidence of loosening of the acetabular component as the end point was $54.2\% \pm 11\%$ for the cable group and $69\% \pm 19\%$ for the wire group ($HR = 1.69$, $p = 0.059$) (Fig. 6).

Discussion

Third-body wear, a complication of fretting and breakage of trochanteric cables or wires, has been reported to be associated with accelerated acetabular polyethylene wear, osteolysis, and loosening in the total hip arthroplasty construct^{1,12}. Bench tribology has shown dramatic increases in wear with roughening or scratching of the femoral head. Finite-element analysis performed in our laboratory showed a sevenfold variation in volumetric wear with roughening¹³. Dowson et al. showed that even single scratches that occurred as a result of

dislocation or other debris (i.e., cement or migrated wires) on an otherwise highly polished stainless steel counterface ($R_a \cong 0.01 \mu\text{m}$) can increase the polyethylene wear rate by more than a factor of 15¹⁴.

Acetabular liner and femoral head retrieval studies by Sychterz et al.¹⁵ and Jasty et al.¹⁶ confirmed that embedded metal debris in the liners and scratches on the femoral head result in accelerated polyethylene wear. Jacobs et al.¹⁷ also demonstrated corrosive by-products from modular femoral head fretting at the bearing surface of the total hip arthroplasty construct, and Clohisy et al.¹⁸ demonstrated accelerated polyethylene wear in cases in which a modular femoral stem was used instead of a nonmodular femoral stem in the total hip arthroplasty construct.

Our results demonstrated poorer outcomes for all measured parameters in association with cable trochanteric reattachment as compared with wire trochanteric reattachment. The median head penetration rate was higher in the cable group than in the wire group; the rate of survival with revision of the acetabular component because of aseptic loosening as the end point was significantly lower for the cable group than for the wire group, and the rate of survival with radiographic loosening of the acetabular component as the end point was lower for the cable group than for the wire group. In addition, the rate of survival with revision of the femoral component because of aseptic loosening as the end point was significantly worse for the cable group than for the wire group and the rate of survival with radiographic evidence of loosening of the femoral component as the end point was worse for the cable group than for the wire group ($p = 0.033$). The rate of acetabular osteolysis also was significantly higher in the cable group, as was the rate of radiographic evidence of acetabular component loosening for living patients.

We also found higher rates of femoral osteolysis, loosening, and revision in the cable group when the entire cohorts were compared and found a higher rate of proximal femoral osteolysis in the cable group when the living patients were compared. An understanding of the concepts of the effective joint space as introduced by Schmalzried et al.¹⁹ can explain these findings, especially in light of the greater amount of particulate debris generated in the cable group. Regardless, the femoral side fared very well clinically, with a survival rate of $>90\%$ at nineteen to twenty years in both groups. With the numbers available, we found no significant differences between linear wear rates in hips with trochanteric union and nonunion. Thus, we concluded that the generation of third-body debris was the primary variable responsible for increased wear, osteolysis, loosening, and revision in the cable group.

The present study had a number of strengths: (1) a single surgeon conducted a sequential, nonselected, and relatively large series; (2) the surgeon was not involved in the analysis; (3) there was a homogenous control group that was treated with identical implants and surgical technique; (4) edge-detection techniques²⁰ were used to measure head penetration in hips with metal-backed components; and (5) at least two observers were used to evaluate radiographs in both groups.

The present study also had a number of weaknesses: (1) the potential for intraobserver and interobserver variability regarding radiographic findings²¹, (2) the use of radiographs for the determination of head penetration and osteolysis (we are aware that newer computed tomography-based algorithms may be more precise²²), and (3) the limited radiographic follow-up of the living patients, with only 70% of the living patients in the two groups having a minimum nineteen to twenty-year follow-up radiograph.

In summary, the cable trochanteric reattachment group performed poorly when compared with the wire trochanteric reattachment group after a comparable period of follow-up. Wear, osteolysis, and radiographic evidence of loosening caused by the generation of cable debris appear to be accelerated by extra-articular cable fretting. We recommend avoiding the use of cables near articular bearing surfaces. In addition, we recommend cable removal if excessive extra-articular fretting is noted, especially if intra-articular cable debris is noted on radiographs. This concern is especially pertinent because, to our knowledge, other than for size, the cables used in the present study are identical to 2.0-mm CoCr cables currently in use. ■

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