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By Jared R.H. Foran, BA, Michael A. Mont, MD, Gracia Etienne, MD, PhD, Lynne C. Jones, PhD, and David S. Hungerford, MD

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Background: Evidence linking increased body weight to osteoarthritis of the knee and the high prevalence of obesity underscore the importance of defining the outcome of total knee arthroplasty in obese patients. The purpose of this study was to compare the clinical and radiographic results of total knee arthroplasties performed in obese patients with those of total knee arthroplasties performed in nonobese patients.

Methods: Clinical and radiographic data on seventy-eight total knee arthroplasties in sixty-eight obese patients were compared with data on a matched group of nonobese patients. The analysis was also performed after stratification of the obese group for the degree of obesity. All patients had the same prosthesis. The clinical data that were analyzed included the Knee Society objective and functional scores, patellofemoral symptoms, activity level, and complications.

Results: The percentage of knees with a Knee Society score of ≥80 points at an average of eighty months was 88% in the obese group, which was significantly lower than the 99% rate in the nonobese group at the same time. The morbidly obese subgroup had a significantly higher revision rate than did the nonobese group ($p = 0.02$).

Conclusions: The results of the present study suggest that any degree of obesity, defined as a body mass index of ≥30, has a negative effect on the outcome of total knee replacement.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See Instructions to Authors for a complete description of levels of evidence.

There is strong evidence linking excessive body weight to degenerative joint disease of the knee[1-7]. Consequently, a large proportion of patients who undergo total knee arthroplasty are obese or morbidly obese[8-13]. Many authors believe that a high body weight will lead to a less-than-optimal outcome of total knee arthroplasty as a result of increased stress across the components and increased load on the surrounding bone[9,14,15].

Several studies have implicated excessive weight as a negative predictor of success of total knee arthroplasty[8-10,12,14,16-19], whereas others have indicated that obesity is not a negative predictor of knee arthroplasty outcomes[11,13,20-27]. Winiarsky et al.[19] compared the outcomes of fifty total knee arthroplasties with cement in forty morbidly obese patients (mean body mass index, 44) with the outcomes of 1768 similar procedures in nonmorbidly obese patients (mean body mass index, 28)[19]. At approximately five years after the operation, the morbidly obese patients had lower objective and functional Knee Society scores as well as higher rates of wound-healing problems and other perioperative complications. In contrast, Spicer et al.[26] found similar ten-year prosthetic survival rates after 385 arthroplasties in 326 obese patients (body mass index, 30) and 425 arthroplasties in 371 nonobese patients.

The purpose of the present study was to compare the clinical and radiographic results of total knee arthroplasties performed in obese patients with those of arthroplasties performed with the same prosthesis in nonobese patients.

Materials and Methods

Between September 1, 1991, and December 31, 1996, 772 total knee arthroplasties were performed with the Duracon total knee prosthesis (Stryker-Howmedica-Osteonics, Allendale, New Jersey). After institutional review board approval was obtained for the study, seventy-eight knees in sixty-eight patients who were obese (defined as a body mass index of ≥30) at the time of the surgery and who had been followed for a minimum of five years were identified from a database of all patients. An additional eight knees in eight obese patients were identified, but four of those patients had died and four had been lost to follow-up and hence were excluded from the study. All of those eight knees were functioning well at the time of the latest follow-up (mean duration, four years; range, two to five years).

The body mass index equals a person's weight in kilo-

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TABLE I Comparison of the Demographic Data of the Obese, Nonobese, Nonmorbidly Obese, and Morbidly Obese Groups

	Nonobese Group	Obese Group	P Value for Difference Between Nonobese and Obese Groups	Nonmorbidly Obese Subgroup	P Value for Difference Between Nonmorbidly Obese and Nonobese Subgroups	Morbidly Obese Subgroup
Follow-up period* *(mo)*	83 ± 19.2 (60 to 123)	80 ± 19.4 (60 to 123)	0.356	81 ± 19.9 (60 to 123)	0.634	79 ± 17.6 (60 to 107)
Age* *(yr)*	70 ± 7.9 (42 to 84)	66 ± 8.6 (32 to 84)	0.002†	66 ± 9.0 (45 to 82)	0.006†	65 ± 5.5 (32 to 84)
Gender *(no. of knees)*						
Men	28	16	0.051‡	13	0.095‡	3
Women	50	62	—	53		9
Body mass index*	26.2 ± 2.5 (17.6 to 29.8)	35.3 ± 4.2 (30.0 to 47.0)	<0.001	33.8 ± 2.6 (30.0 to 39.1)	<0.001	43.2 ± 2.3 (40.0 to 47.0)

*The data (except for the p values) are given as the mean and standard deviation, with the range in parentheses. †Patients were matched for age within ten years. ‡Patients were not matched for gender in order to increase the size of the comparison groups.

grams divided by his or her height in meters squared and correlates well with total body fat[28]. Obesity is defined as a body mass index of ≥30 kg/m^2, and morbid obesity is defined as a body mass index ≥40 kg/m^2 (overweight is defined as a body mass index ≥27 kg/m^2)[28-30].

With use of a list of the obese patients ordered by duration of follow-up (with the patient with the longest duration listed first), each patient was directly matched with the first nonobese, control patient (with a body mass index of <30), hand-selected from a computerized database, who was appropriately matched with respect to the preoperative diagnosis, age at surgery (within ten years), duration of follow-up (within two years), and whether he or she had had a unilateral or bilateral arthroplasty. An attempt was made to match the patients by gender, but this was unsuccessful because there were too many obese women. A separate statistical analysis comparing the results of men and women in the entire group of patients (obese and nonobese) as well as in the individual groups revealed no significant difference in outcome between the two sexes. The authors were blinded to the outcomes at the time of the match. All patients had been followed for a minimum of five years. Seventy-eight knees in sixty-eight nonobese patients were included in the study. Demographic data for each group are summarized in Table I. Follow-up data were obtained by means of a blinded, retrospective review of the computerized database, charts, and radiographs as well as with telephone conversations. The mean duration of follow-up was eighty months (range, sixty to 123 months) for the obese group and eighty-three months (range, sixty to 123 months) for the nonobese group.

The operative technique was the same in all patients. All tibial and patellar components were cemented, and all patellae were resurfaced. A cementless femoral component (a so-called hybrid total knee replacement) was used when there was qualitatively good bone stock and excellent bone cuts had been made. All of the components were cemented in thirty-six knees (46%) in the obese group and forty knees (51%) in the nonobese group, and a hybrid replacement was performed in forty-two knees (54%) in the obese group and thirty-eight knees (49%) in the nonobese group (p = 0.71).

The postoperative activity level of all patients was assessed at the time of the latest follow-up but was utilized to describe the entire activity level throughout the postoperative period. A description of the scoring system can be found in Table II.

All patients were evaluated preoperatively and postoperatively with the Knee Society objective rating scale[31] at the time of the latest follow-up. Ratings of excellent (90 to 100 points) and good (80 to 89 points) were considered to indicate success, whereas ratings of fair (70 to 79 points) and poor (less than 70 points) were considered to indicate failure. Additionally, knees revised or in need of revision because of aseptic loosening, infection, or polyethylene wear or that showed signs of radiographic loosening were considered failures.

Patients were also evaluated for the presence of comorbidities, perioperative complications, wound-healing complications, and patellofemoral symptoms. The status of the patellofemoral joint at the time of the latest follow-up was graded as described by Stern and Insall[12], with grade 0 indicating no symptoms referable to the knee; grade I, mild pain when climbing stairs; and grade II, moderate-to-severe pain when rising from a chair or limiting stair-climbing.

Initial and subsequent postoperative radiographs were examined for changes or progression of abnormalities. Measured parameters included zonal interface lucencies and preoperative and postoperative alignment[31].

The obese group was divided into nonmorbidly obese and morbidly obese subgroups to determine the effects of increasing obesity on outcome. The mean body mass index (and standard deviation) for the obese patients was 35.3 ± 4.2 (range, 30.0 to 47.0). Eleven patients (with twelve knees) in the obese group were morbidly obese, with a mean body mass index of 43.2 ± 2.3 (range, 40.0 to 47.0). The mean body mass index for the nonobese group was 26.2 ± 2.5 (range, 17.6 to 29.8) (Table I).

TABLE II Comparison of Clinical Results of the Obese and Nonobese Groups

	Nonobese Group	Obese Group	P Value
Total no. of knees	78	78	—
Overall result *(no. of knees)*			
Excellent	67	57	—
Good	10	12	—
Fair, poor, or revised	1	9	—
Successful	77 (99%)	69 (88%)	0.02
Failure	1 (1%)	9 (12%)	—
Preop. Knee Society score* *(points)*			
Objective	57 ± 9.0 (30 to 82)	59 ± 11.7 (31 to 80)	0.14
Functional	53 ± 16.2 (15 to 90)	51 ± 16.9 (5 to 90)	0.24
Postop. Knee Society score* *(points)*			
Objective	94 ± 6.5 (62 to 100)	90 ± 12.7 (40 to 100)	0.04
Functional	78 ± 23.4 (0 to 100)	71 ± 23.1 (0 to 100)	0.05
Change in Knee Society objective score (postop. minus preop.)* *(points)*	+37 ± 10.2 (+6 to +70)	+31 ± 16.6 (–33 to +65)	0.01
Patellofemoral symptoms *(no. of knees)*			0.73
Grade 0	40 (51%)	45 (58%)	—
Grade I	28 (36%)	23 (29%)	—
Grade II	10 (13%)	10 (13%)	—
Activity level† *(no. of knees)*			0.72
1	22 (28%)	24 (31%)	—
2	23 (29%)	29 (37%)	—
3	25 (32%)	20 (26%)	—
4	7 (9%)	4 (5%)	—
5	1 (1%)	1 (1%)	—
Periop. complications *(no. of knees)*	0 (0%)	2 (3%)	0.50
Revision *(no. of knees)*	0 (0%)	4 (5%)	0.12
Infection *(no. of knees)*	1 (1%)	1 (1%)	1.00

*The data (except for the p values) are given as the mean and standard deviation, with the range in parentheses. †1 = sedentary (wheelchair, bedridden), 2 = semi-sedentary (light duty), 3 = light labor (yard work), 4 = moderate labor (can lift ≤23 kg and walk >5 km), and 5 = heavy manual labor, vigorous sports.

Data Analysis

The clinical and radiographic outcomes in the obese group were compared with those in the nonobese group. In addition, the outcomes in the nonmorbidly obese and morbidly obese subgroups were stratified and independently compared with those in the nonobese group.

Parametric and nonparametric statistical analysis, with use of the Computer Program for Epidemiological Analysis (PEPI) software package (version 2.03; USD, Stone Mountain, Georgia) and Statistics Calculator (version 5.0; Statpac, Minneapolis, Minnesota), was employed to compare the groups. The significance of differences between groups was determined with the Pearson chi-square test (with use of the Yates correction), Wilcoxon-Mann-Whitney test, Fisher exact test, likelihood ratios, and Student t test. Kaplan-Meier survivorship curves were generated to analyze differences in time to prosthetic failure between the obese and nonobese patients as well as among the morbidly obese, nonmorbidly obese, and nonobese patients. A p value of <0.05 was considered significant.

Results

Sixty-nine (88%) of the seventy-eight knees in the obese group were considered to have a successful outcome at the time of the latest follow-up. Four knees in four obese patients required revision and thus were considered failures, and five knees in five obese patients were considered failures because of a fair or poor Knee Society objective score. In comparison, seventy-seven (99%) of the seventy-eight knee replacements in the nonobese group were successful, and there were no revisions in that group. At the time of the latest follow-up, there

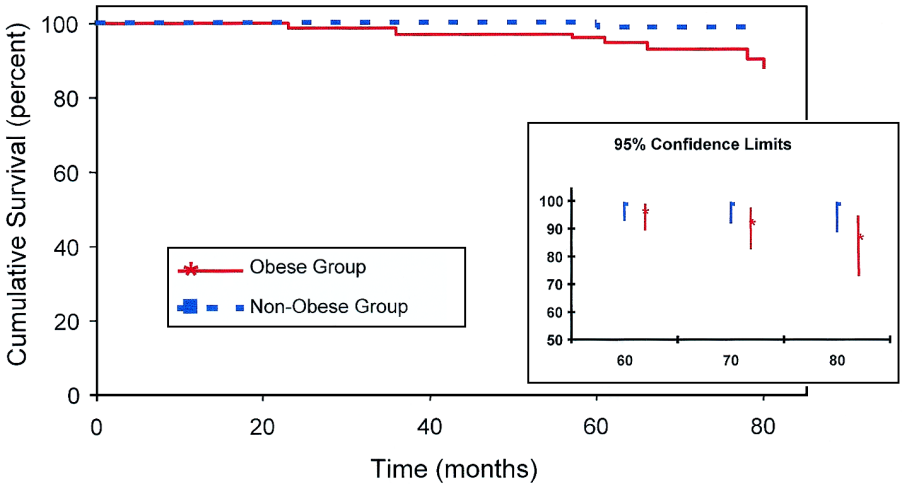

Fig. 1

Kaplan-Meier survivorship curves for failure of the prosthesis, with a reoperation, clinical failure (a Knee Society objective score of <80 points), and radiographic failure as the end points, revealing an 87.7% ± 5.4% (standard error) chance of survival (95% confidence interval, 72.1% to 95.1%) in the obese group and a 98.7% ± 1.9% chance (95% confidence interval, 87.9% to 99.9%) in the nonobese group at eighty months.

was a significant difference in the success rates between the knees in the obese group and those in the nonobese group ($p = 0.02$) (Table II).

Kaplan-Meier survivorship analysis revealed similar rates of prosthetic survival between the obese and nonobese groups until between sixty and eighty months, when the decreased survival rate in the obese group became apparent. At eighty months, the obese group had a6n 87.7% ± 5.4% (standard error) chance of prosthetic survival (95% confidence interval, 72.1% to 95.1%), with a reoperation, clinical failure, and radiographic failure as the end points, and the nonobese group had a 98.7% ± 1.9% chance of prosthetic survival (95% confidence interval, 87.9% to 99.9%) (Fig. 1). The curves were not continued beyond eighty months because the confidence intervals became quite large at that point.

Stratification of knees in the obese group into morbidly and nonmorbidly obese subgroups revealed a lower success rate when those subgroups were compared with the nonobese group. Ten of the twelve knee replacements in the morbidly obese subgroup were successful at the time of the latest follow-up, whereas fifty-nine (89%) of the sixty-six knees in the nonmorbidly obese subgroup and seventy-seven (99%) of the seventy-eight knees in the nonobese group were successful. The rate of success in the nonobese patients was significantly higher than the rate in the nonmorbidly obese patients ($p = 0.02$).

The survivorship curves revealed that, at eighty months, there was a 91.7% ± 11.8% (standard error) chance of prosthetic survival (95% confidence interval, 47.9% to 99.2%) in

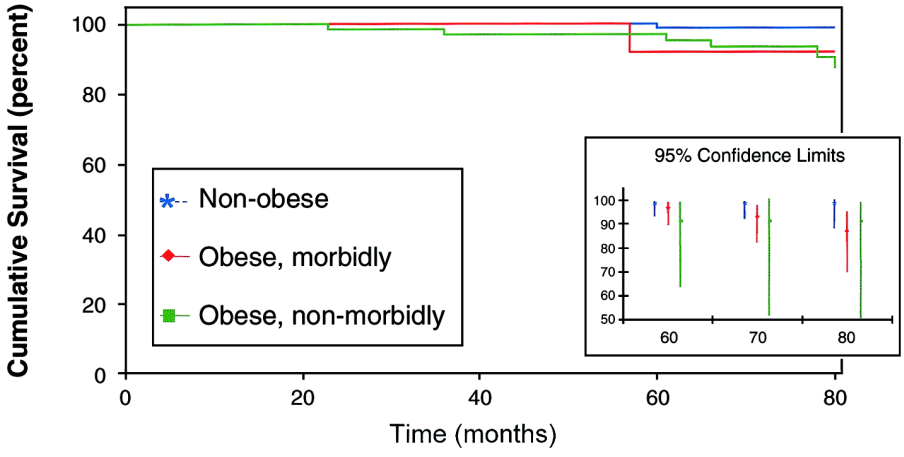

Fig. 2

Kaplan-Meier survivorship curves for failure of the prosthesis, with a reoperation, clinical failure (a Knee Society objective score of <80 points), and radiographic failure as the end points, revealing a 91.7% ± 11.8% (standard error) chance of survival (95% confidence interval, 47.9% to 99.2%) in the morbidly obese subgroup, an 83.6% ± 8.7% chance (95% confidence interval, 58.7% to 94.8%) in the nonmorbidly obese group, and a 98.7% ± 1.9% chance (95% confidence interval, 87.9% to 99.9%) in the nonobese group. Note that the morbidly and nonmorbidly obese groups are subsets of the obese group.

the morbidly obese subgroup (Fig. 2), an 83.6% ± 8.7% chance (95% confidence interval, 58.7% to 94.8%) in the nonmorbidly obese group, and a 98.7% ± 1.9% chance (95% confidence interval, 87.9% to 99.9%) in the nonobese group.

There were no significant differences in the mean preoperative Knee Society objective scores among the groups (Table II), but the mean preoperative functional scores differed significantly between the morbidly obese and nonobese groups ($p < 0.02$). There was a significant difference in the mean postoperative Knee Society objective scores between the obese and nonobese groups (Table II) ($p < 0.05$). There was also a significant difference in the mean changes in the objective Knee Society score (postoperative minus preoperative score) between those groups ($p < 0.05$), although this may be slightly skewed as the obese group started with a 2-point higher mean objective score. The difference in the mean postoperative Knee Society scores between the morbidly obese and nonobese groups was significant as well ($p = 0.04$). There were no differences in revision and infection rates between the nonobese and obese groups. However, the difference in revision rates became significant when the obese group was stratified into morbidly and nonmorbidly obese subgroups and the morbidly obese group was compared with the nonobese group ($p = 0.02$).

The clinical function of the patellofemoral articulation at the time of the latest follow-up in the obese group was grade 0 in forty-five knees (58%), grade I in twenty-three knees (29%), and grade II in ten knees (13%). In the nonobese group, forty knees (51%) had grade-0 function; twenty-eight knees (36%), grade-I; and ten knees (13%), grade-II (Table II). Statistical analysis revealed no difference in patellofemoral scores among the subgroups, with the numbers available. The rates of patellar complications were also similar among the groups. One morbidly obese patient required a patellar revision at 103 months postoperatively, and one nonobese patient required repair of a traumatic rupture of a patellar ligament.

There was no difference in activity levels or the rate of perioperative complications between the obese and nonobese groups (Table II). No patient was bedridden (activity level of 0), and only two patients (one obese and one nonobese patient) had an activity level of 5.

The obese and nonobese patients had similar rates of hypertension, clinically relevant coronary artery disease, and cancer. The obese group had a higher prevalence of diabetes mellitus (eight of sixty-eight patients compared with zero of sixty-eight patients in the nonobese group) ($p = 0.02$).

The radiographic results are presented in the Appendix. No knee that had a good or excellent clinical outcome in either group had impending radiographic failure. There were similar rates of nonprogressive radiolucencies in the three groups, and no knee in any group showed progressive radiolucencies. The postoperative knee-alignment measures were virtually identical among the groups (see Appendix).

Complications

The rates of perioperative complications, including problems with primary wound-healing, were similar in all of the groups. Nine knees in nine obese patients were classified as failures (Table II). Four were considered to be failures because they required revision, whereas the other five were failures because of a fair or poor Knee Society objective score.

Perioperative complications: Two obese patients (two knees) had perioperative complications (a deep vein thrombosis and a wound dehiscence in one patient and a footdrop in the other), whereas none did in the nonobese group. At the time of the latest follow-up, both patients with perioperative complications had a successful Knee Society objective score.

Postoperative complications: Of the four obese patients who required revision, one underwent the reoperation at thirty-six months because of unremitting pain; approximately twelve months later, he underwent a neurectomy to treat continued pain. At forty-four months after the revision, the Knee Society objective score for this patient was poor (65 points) because he continued to have pain at rest. The three other revisions that were done in obese patients were performed because of loosening of a tibial component at fifty-five months after the index arthroplasty, to exchange the polyethylene insert and accomplish a lateral patellar release at 103 months, and to treat a chronic infection at eighty months. All three of those patients eventually had a successful outcome, with Knee Society objective scores of ≥90 points. In addition, five knees in five other obese patients were considered failures because of persistent pain that led to a fair or poor Knee Society objective score. None of those knees showed radiographic signs of impending failure, and no additional surgical treatment was undertaken. In the nonobese group, one knee was considered a failure because of persistent pain, which led to a poor Knee Society objective score of 62 points at sixty months postoperatively.

Discussion

We undertook this study to evaluate the effects of obesity on one type of total knee implant that has been highly successful in the general population[11]. The results suggest that obesity has a negative effect on the outcome of total knee replacement. At a mean of approximately seven years postoperatively, the obese group had a significantly lower rate of success than did the nonobese group. Stratification of the obese group into nonmorbidly obese and morbidly obese subgroups revealed significant differences in revision rates and postoperative objective and functional scores when those subgroups were compared with the nonobese group. Kaplan-Meier survivorship analysis revealed similar rates of prosthetic survival between the two cohorts until between sixty and eighty months, at which time the decrease in the survivorship in the obese group became apparent (Fig. 1). The survival analysis of the morbidly and nonmorbidly obese groups showed a similar pattern of failure (Fig. 2).

Several reports have described the adverse effects of obesity on the outcomes of total knee arthroplasty[8-10,12,14,16-19]. Stern and Insall[12] evaluated the results of 257 knee arthroplasties in 182 patients at a mean of four years (range, two to seven years) postoperatively and found a higher prevalence of patellofemoral symptoms in obese patients. Thirty percent (thirteen) of

forty-three moderately to severely obese patients reported patellofemoral symptoms, whereas 14% (thirty-one) of 214 underweight to mildly obese patients did so ($p < 0.03$). In the present study, obese and nonobese patients had similar rates and severities of patellofemoral symptoms and patellofemoral joint-related complications. This finding is in contrast to the higher prevalence of patellofemoral symptoms experienced by obese patients in the studies by Stern and Insall[12], Pritchett and Bortel[18], and Griffin et al.[14]. This difference may be explained in part by the fact that the prosthesis used in this study had features that were specifically intended to minimize patellofemoral complications[32,33].

Other authors have reported similar overall results in obese and nonobese patients. In the study by Spicer et al.[26], the ten-year prosthetic survival rates were similar for obese and nonobese patients, but obese patients had a higher rate of focal osteolysis on radiographic analysis[29]. Spicer et al. reported slightly lower postoperative Knee Society scores in the obese group but found the absolute improvement in Knee Society scores to be independent of body mass index. This observation is in contradistinction to the findings in the present study, in which obese patients had a smaller mean improvement in the Knee Society score (31 compared with 37 points, $p = 0.01$; Table II). In another report, Mont et al. compared the results of fifty cementless knee arthroplasties in obese patients (body mass index, >30) with those of fifty cementless total knee arthroplasties in a directly matched nonobese group and found no significant difference in Knee Society scores ($p = 0.75$), bead-shedding, or progressive radiolucencies at a mean of sixty-five months (range, twenty-four to 144 months) postoperatively[11]. Other studies[13,20-25] have revealed similar short-term outcomes between obese and nonobese patients. We believe that the results of the present study differ from those of studies showing similar outcomes between obese and nonobese patients because of the longer follow-up of directly matched patients in our study.

We also found no differences in activity levels or perioperative complication rates between the groups. In addition, the radiographic results were similar among the groups, which is in contrast to the findings of Spicer et al., who reported a focal osteolysis rate in obese patients that was five times greater than that in nonobese patients[26], and the observations by Griffin et al., who found a higher prevalence of nonprogressive radiolucent lines in obese patients[14].

Some of the findings in our study are limited by the small numbers of patients available. In addition, the patients could not be directly matched for gender because of the disproportionately higher number of women in the obese group. Nevertheless, the two groups were matched for age, diagnosis, duration of follow-up, and unilaterality or bilaterality, and they had similar preoperative Knee Society objective and functional scores.

In summary, the key findings in the present study are that obese patients had a lower success rate and lower postoperative Knee Society scores and, therefore, lower satisfaction levels. Overall, it appears that obesity has a negative impact on the results of total knee arthroplasty, with morbid obesity having an even more dramatic negative effect with regard to revision rates after total knee arthroplasty.

Appendix

(eA) Tables describing findings with regard to radiolucency and alignment of the implants are available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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