ORIGINAL ARTICLE

Total Hip Replacement or Resistance Training for Severe Hip Osteoarthritis

Thomas Frydendal, Ph.D., Robin Christensen, Ph.D., Inger Mechlenburg, D.M.Sc., Lone R. Mikkelsen, Ph.D., Claus Varnum, Ph.D., Anders E. Graversen, M.D., Per Kjærsgaard-Andersen, M.D., Peter H. Revald, M.D., Christian Hofbauer, M.D., Manuel J. Bieder, M.D., Haidar Qassim, M.D., Mohammad S. Munir, Ph.D., Stig S. Jakobsen, Ph.D., Sabrina M. Nielsen, Ph.D., Kim G. Ingwersen, Ph.D., and Søren Overgaard, D.M.Sc.

ABSTRACT

BACKGROUND

Total hip replacement is routinely recommended for severe hip osteoarthritis, but data from randomized trials are lacking regarding comparison of the effectiveness of this procedure with that of nonsurgical treatment such as resistance training.

METHODS

We conducted a multicenter, randomized, controlled trial to compare total hip replacement with resistance training in patients 50 years of age or older who had severe hip osteoarthritis and an indication for surgery. The primary outcome was the change in patient-reported hip pain and function from baseline to 6 months after the initiation of treatment, assessed with the use of the Oxford Hip Score (range, 0 to 48, with higher scores indicating less pain and better function). Safety was also assessed.

RESULTS

A total of 109 patients (mean age, 67.6 years) were randomly assigned to total hip replacement (53 patients) or resistance training (56 patients). In an intention-to-treat analysis, the mean increase (indicating improvement) in the Oxford Hip Score was 15.9 points in patients assigned to total hip replacement and 4.5 points in patients assigned to resistance training (difference, 11.4 points; 95% confidence interval, 8.9 to 14.0; P<0.001). At 6 months, 5 patients (9%) who had been assigned to total hip replacement had not undergone surgery, and 12 patients (21%) who had been assigned to resistance training had undergone total hip replacement. The incidence of serious adverse events at 6 months was similar in the two groups; the majority of such events were known complications of total hip replacement.

CONCLUSIONS

In patients 50 years of age or older who had severe hip osteoarthritis and an indication for surgery, total hip replacement resulted in a clinically important, superior reduction in hip pain and improved hip function, as reported by patients, at 6 months as compared with resistance training. (Funded by the Danish Rheumatism Association and others; PROHIP ClinicalTrials.gov number, NCT04070027.)

The authors' affiliations are listed in the Appendix. Dr. Frydendal can be contacted at thomas.frydendal@rsyd.dk or at Vejle Hospital, Beriderbakken 4, 7100 Vejle, Denmark.

Drs. Ingwersen and Overgaard contributed equally to this article.

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Hip osteoarthritis is a substantial contributor to disability, affecting 33 million persons worldwide.[1,2] Across Europe and Australia, the lifetime likelihood of undergoing total hip replacement is 8 to 16%.[3,4] This procedure effectively alleviates hip pain, reduces functional impairment, and improves quality of life, with up to 86% of patients reporting satisfaction with outcomes 6 months after surgery.[5,6] More than 1 million total hip replacements are performed yearly worldwide,[5] with the annual rate predicted to increase by 284% in the United States by 2040 as compared with 2014,[7] a situation that highlights a greater future burden on health care systems.

Despite the frequency of total hip replacement, data from randomized trials are lacking regarding comparison of the effectiveness of the procedure with that of nonsurgical treatment for hip osteoarthritis.[8,9] Direct comparisons are warranted, given that many common orthopedic procedures have been shown in randomized trials to be no more effective than nonsurgical treatment.[8,9] Exercise is consistently recommended in the nonsurgical management of hip osteoarthritis,[10,11] and resistance training appears to lead to a moderate reduction in hip pain and improved function, even in patients who are scheduled to undergo total hip replacement.[12,13] We conducted the Progressive Resistance Training versus Total Hip Arthroplasty (PROHIP) randomized trial involving patients 50 years of age or older who had severe hip osteoarthritis and an indication for surgery in order to evaluate whether total hip replacement would provide superior results regarding alleviation of patient-reported hip pain and improved patient-reported function as compared with resistance training.

Methods

Trial Design and Oversight

In this multicenter, randomized, controlled, superiority trial, we randomly assigned, in a 1:1 ratio, patients to undergo total hip replacement or to participate in a supervised resistance training program. Follow-up assessments were conducted at 3, 6, 12, and 24 months after the initiation of treatment. The trial was approved by the Regional Committees on Health Research Ethics for Southern Denmark and by the Danish Data Protection Agency. All the patients provided written informed consent. The trial protocol, which is available with the full text of this article at NEJM.org, was published previously.[14] All the authors vouch for the accuracy and completeness of the data and for the fidelity of the trial to the protocol.

A Quick Take is available at NEJM.org

Patients

Patients 50 years of age or older who had severe hip osteoarthritis and an indication for total hip replacement on the basis of hip pain, clinical presentation, and radiographic imaging, as assessed by a specialist in orthopedic surgery at one of four public orthopedic departments in Denmark, were considered to be eligible for trial enrollment. Exclusion criteria were severe walking deficits (dependency on two crutches or a walker); a body-mass index (the weight in kilograms divided by the square of the height in meters) of more than 35; fracture of the leg or foot within the previous 12 months; planned surgery of the leg or foot within the next 6 months; cancer and current receipt of chemotherapy, immunotherapy, or radiotherapy; neurologic disease; and other reasons such as an inability to understand Danish or a status of being considered to be mentally or physically unable to participate.

Patients were informed of the trial after eligibility was confirmed by the orthopedic surgeon. Research coordinators provided each patient with detailed standardized information about current clinical practice and evidence for the two treatments and obtained written informed consent.[15]

Trial Procedures

After the baseline assessment, patients were randomly assigned to undergo total hip replacement (hip-replacement group) or to participate in resistance training (resistance-training group). Randomization was conducted with the use of a computer-generated randomization sequence with varying block sizes (two to six) and with stratification according to hospital. Treatment assignment was concealed until a local trial coordinator completed the randomization in the electronic management system after the baseline assessment. Patients and clinicians were aware of the treatment assignments. Outcome assessors, investigators, and the biostatistician were unaware of the treatment assignments.

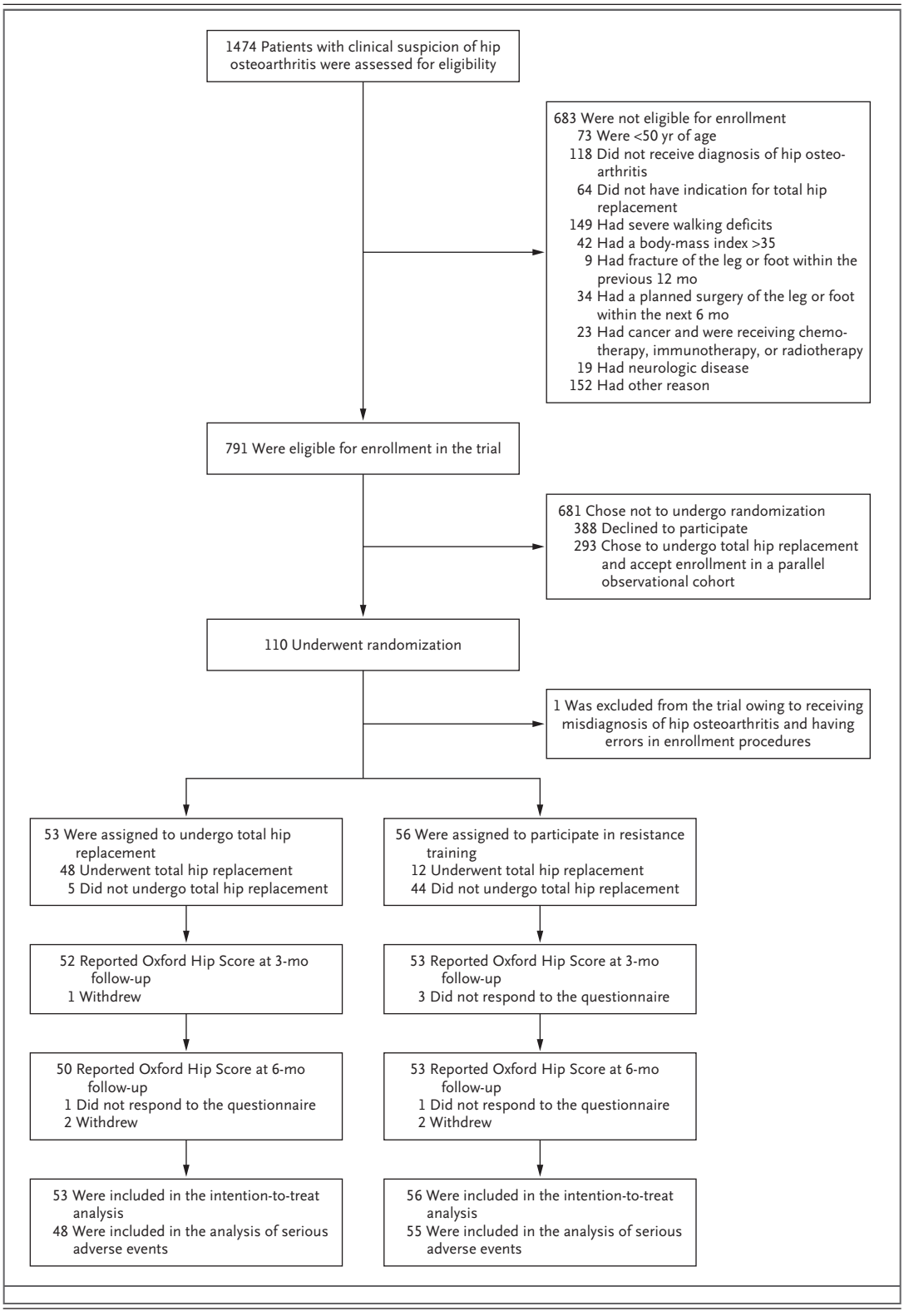


Figure 1 (facing page). Trial Enrollment and 6-Month Follow-up.

The analysis of serious adverse events was based on the safety population, which included the patients assigned to the hip-replacement group who underwent surgery and the patients assigned to the resistance-training group who participated in at least one training session.

TRIAL TREATMENTS

The total hip replacement procedure was delivered as a standard fast-track surgical program that included preoperative education, pain management, and early mobilization.[16] Orthopedic surgeons with specialty in hip surgery performed the total hip replacement using the posterior surgical approach.[17] Patients were instructed postoperatively in a home-based exercise program[14] and were referred to participate in supervised exercise if needed.[18] Satisfactory treatment adherence in the hip-replacement group was defined as the completion of surgery.

The resistance training program was delivered by physiotherapists in 1-hour, individual, supervised sessions twice weekly for 12 weeks. The standardized protocol comprised a 10-minute warm-up on a stationary bike followed by four resistance exercises (leg press, hip extension, hip flexion, and hip abduction) that were performed for both legs, one at a time, with the use of weight machines or cable pulleys for three sets separated by 60 seconds of rest. Progression followed a linear periodization model in which the number of repetitions decreased as the training load increased, from 12 repetitions per set during weeks 1 and 2 to 8 repetitions per set during weeks 7 through 12. The training load between each set was adjusted according to the ability of the patient to complete as many repetitions as possible until muscle failure; hip-pain response was used to guide the training load between sessions.[13] After the supervised sessions were completed, patients were offered 12 weeks of exercise, to be conducted on their own, at a training facility of their choice. Satisfactory treatment adherence in the resistance-training group was defined as attendance at 18 or more of the 24 supervised sessions. Detailed descriptions of both treatments are available in the trial protocol[14] and the Supplementary Appendix (available at NEJM.org).

OUTCOMES

We assessed outcome measures for pain, function, and serious adverse events according to current recommendations.[19] The primary outcome was the change in patient-reported hip pain and function from baseline to 6 months as assessed by means of the Oxford Hip Score.[20,21] This 12-item patient-reported questionnaire assesses hip pain and function in one total score, on a scale from 0 to 48, with higher scores indicating less pain and better function[20,21]; the minimal clinically important difference is estimated to be 5 points.[22]

Secondary outcomes included changes from baseline to 6 months in patient-reported domains of pain, symptoms, function in activities of daily living, hip-related quality of life, and function in sports and recreation, as assessed by the Hip Disability and Osteoarthritis Outcome Score subscales (range, 0 [worst] to 100 [best]; minimal clinically important difference, 10 points).[23,24] Additional secondary outcomes were the changes from baseline to 6 months in the patient-reported physical activity level as assessed by the University of California, Los Angeles (UCLA), activity score (range, 1 [inactive] to 10 [regular physical activity with high intensity]; minimal clinically important difference, 2 points)[25] and in functional performance in two tasks. The two functional-performance tasks were the 40-m fast-paced walk test,[26] in which gait speed is measured in meters per second, and the 30-second sit-to-stand test,[26] in which the number of completed stands from sitting in a chair per 30 seconds is counted; the estimated clinically important improvements were considered to be an increase of 0.20 m per second and an increase of 2.1 repetitions, respectively.[27]

Serious adverse events that occurred between baseline and 6 months were identified from hospital records and patient reports with the use of an open-ended questionnaire. An independent auditing committee classified and assessed all the adverse events for severity, according to the guidelines of the International Council for Harmonisation.[28] We had planned to collect data on serious adverse events from the Danish National Patient Registry, but substantial delays in application processing due to the coronavirus disease 2019 pandemic prevented this.

Table 1. Characteristics of the Patients at Baseline.*

Characteristic	Total Hip Replacement (N=53)	Resistance Training (N=56)
Age — yr	67.5±7.3	67.6±7.1
Female sex — no. (%)	26 (49)	28 (50)
Body-mass index	27.9±3.9	28.2±3.8
Educational level above high school — no. (%)	29 (55)	28 (50)
Employment status — no. (%)		
Employed for wages or self-employed	19 (36)	16 (29)
On sick leave	1 (2)	2 (4)
Retired	32 (60)	38 (68)
Other	1 (2)	0
Current smoking — no. (%)	1 (2)	4 (7)
Alcohol intake of >10 units/wk — no. (%)†	6 (11)	7 (12)
Median duration of hip symptoms (IQR) — yr	2.0 (1.0–3.0)	1.5 (0.7–4.0)
Previous total hip arthroplasty — no. (%)	2 (4)	9 (16)
Previous total knee arthroplasty — no. (%)	1 (2)	1 (2)
Previous treatment for hip-related pain — no. (%)		
Supervised exercise	14 (26)	17 (30)
Manual or passive treatment	7 (13)	10 (18)
Glucocorticoid injection	1 (2)	2 (4)
Other nonsurgical treatment	5 (9)	8 (14)
Use of analgesic agents for hip-related pain — no. (%)		
Acetaminophen	38 (72)	45 (80)
Nonsteroidal antiinflammatory drug	22 (42)	17 (30)
Opioid	5 (9)	3 (5)
Other analgesic agent	5 (9)	4 (7)
Oxford Hip Score‡	25.4±6.2	24.8±5.6
Hip Disability Osteoarthritis Outcome Score subscales§		
Pain	49.7±13.4	46.0±16.3
Symptoms	47.7±18.5	44.0±16.8
Function in activities of daily living	55.8±17.1	52.5±17.7
Hip-related quality of life	34.0±16.0	34.0±15.0
Function in sports and recreation	32.0±19.3	31.1±20.4
UCLA activity score¶	5.3±1.8	5.1±1.7
Gait speed in the 40-m fast-paced walk test — m/sec	1.5±0.3	1.4±0.3
No. of repetitions in the 30-sec sit-to-stand test	11.1±3.6	10.6±3.4

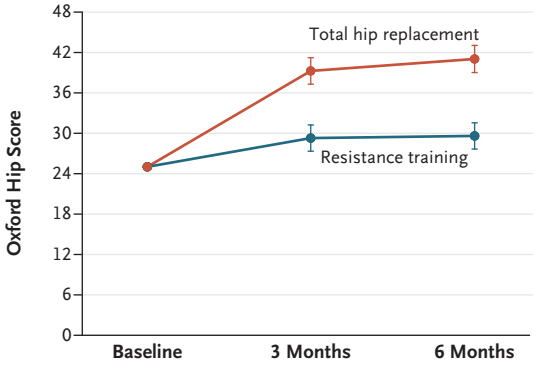
* Plus–minus values are means ±SD. Percentages may not total 100 because of rounding. IQR denotes interquartile range.
† One unit equals 10 ml or 8 g of pure alcohol.
‡ The Oxford Hip Score measures hip pain and function in one total score, on a scale from 0 to 48, with higher scores indicating less pain and better function.
§ The Hip Disability Osteoarthritis Outcome Score includes subscales for pain, symptoms, function in activities of daily living, hip-related quality of life, and function in sports and recreation, with scores on each subscale ranging from 0 (worst) to 100 (best).
¶ The University of California, Los Angeles (UCLA), activity score measures the level of physical activity on a scale from 1 (inactive) to 10 (regular physical activity with high intensity).

STATISTICAL ANALYSIS

A detailed statistical analysis plan was made publicly available before the final deadline for patient enrollment. An independent biostatistician performed the statistical analyses, and the trial steering committee followed published procedures for blinded interpretation of the intention-to-treat analysis.[29] The main analysis used the treatment policy estimand, which quantified the average treatment effect among all the patients who had undergone randomization, regardless of adherence to treatment or crossover (i.e., the intention-to-treat population). The analysis of serious adverse events was based on the safety population, which included the patients assigned to the hip-replacement group who underwent surgery and the patients assigned to the resistance-training group who participated in at least 1 training session. Additional analyses that were based on the per-protocol population (patients assigned to the hip-replacement group who underwent surgery and patients assigned to the resistance-training group who participated in ≥18 of 24 training sessions) and the as-treated population (patients who underwent total hip replacement and those who did not undergo surgery, independent of randomization) aimed to explore the effects of treatment adherence but without statistical inferences.[30] These analyses and a simplistic imputation of nonresponse with the use of baseline observation carried forward for missing data were performed to assess the robustness of the main intention-to-treat analysis. Analyses of serious adverse events and robustness were performed after the randomization code was broken. The statistical analysis plan and information about the blinded interpretation are provided in the Supplementary Appendix.

On the basis of previous data,[12,13,22] we estimated that a sample of 60 patients per group would provide the trial with 92% power to detect a mean (±SD) minimal clinically important difference between the two groups of 5±8 points in the change in the Oxford Hip Score, at a two-sided alpha level of 0.05. For the trial to obtain at least 80% power, we calculated that a sample of 42 patients per group would be required. In agreement with the prespecified recruitment deadline,[14] patient enrollment ended after 22 months.

To account for multiplicity and preserve the overall type I error for the numerous secondary outcomes, a gatekeeping strategy was used. Secondary outcomes were tested in the following order: Hip Disability and Osteoarthritis Outcome Score in the five domains of pain, symptoms, function in activities of daily living, hip-related quality of life, and function in sports and recreation; the UCLA activity score; the 40-m fast-paced walk test; and the 30-second sit-to-stand test, with interpretation applicable only if the between-group differences for the preceding outcomes were significant (P<0.05).



No. of Observations	Baseline	3 Months	6 Months
Total hip replacement	53	52	50
Resistance training	56	53	53

Figure 2. Trajectories in the Oxford Hip Score during 6 Months of Follow-up.
The Oxford Hip Score measures hip pain and function in one total score, on a scale from 0 to 48, with higher scores indicating less pain and better function. The values plotted are least-squares means, and I bars indicate 95% confidence intervals.

Analyses of treatment response that were not included in the hierarchical analysis were performed to compare the proportion of patients who had an improvement in their condition according to the minimal clinically important change of at least 8 points on the Oxford Hip Score[22] or according to the Outcome Measures in Rheumatology–Osteoarthritis Research Society International criteria.[31]

Continuous outcomes were analyzed as the change from baseline with the use of repeated-measures mixed-effects linear models with the patient identification number as a random effect and with the baseline score, treatment group (total hip replacement or resistance training), time (baseline, 3 months, 6 months, 12 months, or 24 months), hospital location (Vejle, Odense, Aarhus, or Næstved), and interactions between treatment groups and time as fixed-effect factors. Missing data were handled with the use of the

Table 2. Outcomes at 6 Months (Intention-to-Treat Population).*

Outcome	Change from Baseline to 6 Mo		Adjusted Mean Difference (95% CI)	P Value
	Total Hip Replacement (N=53)	Resistance Training (N=56)		
Primary outcome				
Oxford Hip Score	15.9±1.0	4.5±1.0	11.4 (8.9 to 14.0)	<0.001
Secondary outcomes				
Hip Disability Osteoarthritis Outcome Score subscales				
Pain	39.2±2.4	15.0±2.3	24.2 (18.2 to 30.2)	<0.001
Symptoms	39.3±2.5	13.6±2.4	25.7 (19.5 to 31.8)	<0.001
Function in activities of daily living	32.9±2.2	12.1±2.1	20.8 (15.2 to 26.3)	<0.001
Hip-related quality of life	43.5±3.1	10.7±3.0	32.7 (25.0 to 40.4)	<0.001
Function in sports and recreation	41.0±2.8	9.2±2.7	31.8 (24.9 to 38.8)	<0.001
UCLA activity score	1.2±0.2	0.5±0.2	0.7 (0.1 to 1.3)	0.02
Median gait speed in the 40-m fast-paced walk test (IQR) — m/sec†	0.15 (0.05 to 0.33)	0.06 (–0.05 to 0.19)	0.10 (0.03 to 0.17)	0.009
Median no. of repetitions in the 30-sec sit-to-stand test (IQR)†	1 (0 to 4)	1 (0 to 3)	0 (–1 to 2)	0.36
Treatment response				
Met minimal clinically important change criteria for Oxford Hip Score — no. (%)‡	40 (75)	21 (38)	38 (21 to 55)	
Met OMERACT-OARSI criteria — no. (%)§	41 (77)	21 (38)	40 (23 to 57)	

* Plus–minus values are least-squares means ±SE. All the analyses were based on the intention-to-treat population, which included all the patients who had undergone randomization. For continuous outcomes, repeated-measures linear mixed-effects models (with no imputation for missing data) were used for estimating least-squares means with standard errors and between-group differences with 95% confidence intervals. For dichotomous outcomes, numbers and percentages of patients and between-group differences (in percentage points) with 95% confidence intervals were estimated with the use of a conservative imputation for nonresponse. In the assessments of treatment response, the 95% confidence intervals were not adjusted for multiplicity and should not be used in place of hypothesis testing.

† Medians with interquartile ranges and median differences with 95% confidence intervals are reported for the outcomes of gait speed in the 40-m fast-paced walk test and the number of repetitions in the sit-to-stand test, with no imputation for missing data. For these outcomes, data were missing for four patients in the hip-replacement group and for five in the resistance-training group.

‡ With regard to the minimal clinically important change criteria for the Oxford Hip Score, patients were defined as having a response if the Oxford Hip Score increased (indicating improvement) by at least 8 points.

§ With regard to the Outcome Measures in Rheumatology–Osteoarthritis Research Society International (OMERACT-OARSI) criteria, patients were defined as having a response if the Oxford Hip Score pain or function subscale scores (on a scale from 0 [worst] to 100 [best]) increased (indicating improvement) by 50% or more and by 20 points or more or if two of the following three criteria were met: the pain subscale score of the Oxford Hip Score increased by 20% or more and by 10 points or more, the function subscale score of the Oxford Hip Score increased by 20% or more and by 10 points or more, or the total Oxford Hip Score (on a scale from 0 [worst] to 48 [best]) increased by 20% or more and by 10 points or more.

mixed-effects linear-models approach with an assumption that data were missing at random, in accordance with the working assumption underlying these models.[32] Dichotomous outcomes were analyzed by means of logistic regression with identical fixed-effect factors and covariates as the mixed-effects linear models and with missing data handled with the use of imputation of nonresponse, in which patients who did not have a response or who withdrew were considered not to have had a response.

Changes from baseline were reported as least-squares means with standard errors, and between-group differences are presented as least-squares means with 95% confidence intervals. A two-sided P value of less than 0.05 was considered to indicate statistical significance. Results regarding treatment response are reported as numbers, percentages, and between-group differences with 95% confidence intervals. Trajectories in the Oxford Hip Score from baseline to 6 months are presented. Analyses were performed with the use

of R software, version 4.2.2 (R Foundation for Statistical Computing).

RESULTS

CHARACTERISTICS OF THE PATIENTS AND TREATMENT ADHERENCE

From September 2019 through June 2021, we assessed 1474 patients for eligibility, of whom 791 (54%) were eligible. Of these patients, 109 (14%) were randomly assigned to one of the two treatment groups, with 53 patients assigned to undergo total hip replacement and 56 to participate in resistance training (Fig. 1). The mean age of the patients was 67.6 years, 50% were women, and the median duration of hip symptoms was 1.7 years. The characteristics of the patients at baseline were balanced between the groups, except that the percentage of patients who had undergone previous contralateral total hip replacement was higher in the resistance-training group than in the hip-replacement group (Table 1).

The median time from randomization to the initiation of treatment was 2.8 months (interquartile range, 1.9 to 3.9) in the hip-replacement group and 0.5 months (interquartile range, 0.4 to 0.8) in the resistance-training group, and the median follow-up after the initiation of treatment was 6.0 months (interquartile range, 6.0 to 6.2) and 6.1 months (interquartile range, 6.0 to 6.2), respectively. In the hip-replacement group, 48 patients (91%) had undergone the procedure at the 6-month follow-up, and 5 patients (9%) declined or canceled surgery after doing exercise. In the resistance-training group, 55 patients (98%) began the treatment program, and 47 (84%) completed the program with satisfactory adherence (defined as attendance at ≥18 supervised sessions). A total of 12 patients (21%) in the resistance-training group underwent total hip replacement by 6 months of follow-up owing to an increase or no abatement in hip pain (Table S1 in the Supplementary Appendix).

Table 3. Serious Adverse Events at 6 Months of Follow-up (Safety Population).*

Event	Total Hip Replacement (N=48)	Resistance Training (N=55)
	number (percent)	
Musculoskeletal event		
Prosthetic joint infection	1 (2)	0
Hip dislocation	1 (2)	1 (2)†
Revision surgery	2 (4)	0
Pelvic fracture and distal radius fracture	0	1 (2)‡
Total shoulder replacement	0	1 (2)§
Cardiovascular event: atrial fibrillation	0	1 (2)¶
Nervous system event: drop foot	1 (2)	0
Gastrointestinal event: reflux	1 (2)	0
Renal event: urinary tract infection and kidney infection	0	1 (2)
Discontinuation due to serious adverse event	0	1 (2)†
Any serious adverse event	6 (12)	5 (9)

* The safety population included the patients assigned to the hip-replacement group who underwent surgery and the patients assigned to the resistance-training group who participated in at least one training session. Serious adverse events that occurred between baseline and the 6-month follow-up but that did not necessarily have a causal relationship with the treatments are reported. All the adverse events were adjudicated for severity, according to the guidelines of the International Council for Harmonisation (i.e., any untoward medical occurrence that resulted in death, was life-threatening, led to hospitalization or prolongation of hospitalization, resulted in persistent or significant disability or impairment, or resulted in a congenital anomaly or birth defect was classified as a serious adverse event). No deaths occurred between baseline and the 6-month follow-up.

† Hip dislocation in one patient in the resistance-training group occurred after the patient had undergone total hip replacement, and the event led to discontinuation in the trial.

‡ Pelvic and distal radius fractures in one patient in the resistance-training group occurred as a result from a fall during a leisure-time activity.

§ Total shoulder replacement occurred in one patient in the resistance-training group who had a known condition causing persistent shoulder pain.

¶ Atrial fibrillation in one patient in the resistance-training group occurred after the patient had undergone total hip replacement.

OUTCOMES

The mean increase (indicating improvement) in the Oxford Hip Score from baseline to 6 months was 15.9 points in the hip-replacement group, as compared with 4.5 points in the resistance-training group (mean between-group difference, 11.4 points; 95% confidence interval [CI], 8.9 to 14.0; P<0.001) (Fig. 2). An increase of at least 8 points on the Oxford Hip Score was observed in 40 patients (75%) in the hip-replacement group and in 21 patients (38%) in the resistance-training group (between-group difference, 38 percentage points; 95% CI, 21 to 55), and consistent values were observed with regard to the Outcome Measures in Rheumatology–Osteoarthritis Research Society International criteria (Table 2).

At 6 months, the hip-replacement group had significantly more improvement than the resistance-training group in all Hip Disability and

Osteoarthritis Outcome Score subscale scores, the UCLA activity scale score, and gait speed. The median improvement in the sit-to-stand function was similar in the two groups (Table 2). Analyses that were based on the per-protocol and as-treated populations and that used imputation of nonresponse yielded results similar to those of the main analysis (Tables S2, S3, and S4).

SERIOUS ADVERSE EVENTS

At least one serious adverse event occurred in 6 of 48 patients (12%) in the hip-replacement group and in 5 of 55 patients (9%) in the resistance-training group. Across the two groups, eight of the serious adverse events occurred after total hip replacement, including two events in patients in the resistance-training group who crossed over to surgery (Table 3).

LONG-TERM FOLLOW-UP

A total of 100 patients completed 12 months of follow-up, and 97 patients completed 24 months of follow-up (Fig. S1). Trajectories in the Oxford Hip Score and the Hip Disability and Osteoarthritis Outcome Score subscale scores favored the hip-replacement group up to 12 months, whereas all patient-reported outcomes were similar in the two groups at 24 months (Tables S5 and S6). In the resistance-training group, 33 patients (59%) had undergone total hip replacement at 12 months, and 43 (77%) had done so at 24 months (Table S7).

DISCUSSION

In this multicenter, randomized trial involving patients 50 years of age or older who had severe hip osteoarthritis and indication for surgery, total hip replacement resulted in clinically important, superior improvements as compared with resistance training at 6 months of follow-up, as assessed by means of patient-reported hip pain and function as measured by the Oxford Hip Score, as well as in individual measures of patient-reported pain, function, symptoms, and quality of life. Total hip replacement did not lead to clinically important greater improvements than resistance training with regard to physical activity level, gait speed, or sit-to-stand function at 6 months. Although the incidence of serious adverse events at 6 months was similar in the two groups, the majority of such events were known complications of total hip replacement.

Data from trials evaluating the effectiveness of total hip replacement as compared with nonsurgical treatment have been limited.[8,9] In this trial, we observed improvements in patient-reported and functional performance outcomes after total hip replacement or resistance training that were similar to those reported in previous studies.[12,13,33-35] Although our results favor treatment with total hip replacement for most outcomes, they do not oppose the use of resistance training as initial treatment. In this regard, nearly three of four patients had not received exercise therapy before enrollment, and almost one in four who had been assigned to resistance training had not undergone surgery after 24 months. Although interpretation of the magnitude of improvement is challenging without a sham control, our results suggest that resistance training may be a viable treatment option for some patients with severe hip osteoarthritis, as suggested by a previous randomized trial.[13] Even for patients who ultimately undergo total hip replacement, previous studies support faster postoperative recovery in those who undergo supervised resistance training than in those who do not.[36,37]

Our trial has some limitations. First, the trial was not blinded, given that we did not consider sham surgery or sham exercise to be feasible. This situation may have resulted in overestimation of the effects of both treatments and of the relative benefit of surgery as compared with exercise.[38-40] Given that patients in each group received multimodal treatments that included education and pain management, separating the effects of each method was not possible. Only 14% of the eligible patients were enrolled, so the results of this trial must be generalized with caution. The most common reason for patients declining enrollment was a treatment preference for total hip replacement. Since treatment preference may be associated with outcome, our trial may be prone to selection bias because the enrolled patients may differ from the general population of persons with hip osteoarthritis. However, the distributions of sex, age, and body-mass index in our trial population were similar to those of patients undergoing total hip replacement across the world (Table S8). Furthermore, the baseline values for the Oxford Hip

Score did not differ materially from those that have been reported by patients in Australia, Denmark, and the Netherlands (Tables S9 and S10), which supports the external validity of our trial.

Because 9% of the patients in the hip-replacement group decided not to undergo surgery and 21% of those in the resistance-training group had undergone surgery at 6 months, our results may underestimate the true difference between the treatments at that follow-up time. Specifically, the higher percentages of patients who crossed over to surgery at 12 months and 24 months imply greater underestimation of surgical benefits with longer follow-up. Moreover, we did not formally assess treatment expectations before randomization. The higher proportion of patients with previous contralateral total hip replacements in the resistance-training group than in the hip-replacement group at baseline may have influenced the patients' expectations of resistance training and affected our estimates of treatment effect.

In this trial involving patients 50 years of age or older who had severe hip osteoarthritis and an indication for surgery, we found that total hip replacement resulted in clinically important, superior reductions in patient-reported hip pain and improvements in function at 6 months as compared with resistance training. These results support current recommendations for the management of hip osteoarthritis[10,11] and may be used to inform and guide shared decision making in clinical practice.

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A data sharing statement provided by the authors is available with the full text of this article at NEJM.org.

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APPENDIX

The authors' affiliations are as follows: the Departments of Physiotherapy (T.F., K.G.I.) and Orthopedic Surgery (C.V., A.E.G., P.K.-A., P.H.R., C.H.), Lillebaelt Hospital–University Hospital of Southern Denmark, Vejle Hospital, Vejle, the Departments of Clinical Research (T.F., R.C., S.M.N.) and Regional Health Research (C.V., K.G.I.), University of Southern Denmark, and the Research Unit of Rheumatology, Department of Clinical Research (R.C., S.M.N.), and the Department of Orthopedic Surgery and Traumatology (S.O.), Odense University Hospital, Odense, the Section for Biostatistics and Evidence-based Research, Parker Institute, Bispebjerg and Frederiksberg Hospital (T.F., R.C., S.M.N., K.G.I.), the Department of Orthopedic Surgery and Traumatology, Copenhagen University Hospital Bispebjerg (S.O.), and the Department of Clinical Medicine, Faculty of Health and Medical Sciences, University of Copenhagen (S.O.), Copenhagen, the Department of Orthopedic Surgery, Aarhus University Hospital, and the Department of Clinical Medicine, Aarhus University, Aarhus (I.M., S.S.J.), the University Clinic for Orthopedic Pathways, Elective Surgery Center, Regional Hospital Silkeborg, Silkeborg (L.R.M.), and the Department of Orthopedic Surgery, Næstved Hospital, Næstved (M.J.B., H.Q., M.S.M.) — all in Denmark.

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