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A COMPARISON OF THE FUNCTIONAL PERFORMANCE OF PATIENTS WITH CHARNLEY AND MÜLLER TOTAL HIP REPLACEMENT

A Two-Year Follow-up of Eighty-Nine Cases

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Measurements of functional performance in 35 cases with Charnley total hip replacement were compared with those of 54 cases with Müller replacement before surgery and at 6- and 24-month follow-up intervals. The measurements included strength of the hip abductor and adductor muscles, hip motion, the amount of weight borne on the involved limb during standing posture, multiple components of free-speed and fast walking, and force applied to canes and crutches. Both replacement groups improved significantly in most components of function. In fact, both groups reached or nearly reached the lower limits of normal variability in weight-bearing ability, cadence, and some components which relate to smoothness of walking performance. The groups with Müller and Charnley replacement differed most in some components of range of hip motion, hip muscle strength, and lateral lurching during walking.

Key words: arthritis; biomechanics; gait; hip joint; joint prosthesis; muscle contraction

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The purpose of this study is to determine whether there are differences in the functional performance between patients with Müller and Charnley total hip replacements. The determination is based on comprehensive kinesiologic measurements of functional performance before surgery and 6 and 24 months after surgery.

METHODS

Initially, a total of 104 consecutive patients with 119 hip replacements were referred for this study. Tests were completed on 75 patients (89 total hip replacements) who fulfilled the criteria for inclusion in this comparative study. The criteria were that the total hip replacement be uncomplicated by loosening or infection and that the patients have no neurological disease or major problems with other joints in the lower extremities. Twenty-nine patients had 35 Charnley replacements and 46 had 54 Müller replacements. There were 16 women and 13 men with Charnley replacement and 25 women and 21 men with Müller replacement. Patients with Charnley replacement averaged 61 years of age (range, 22–77) and patients with Müller replacement averaged 63 years of age (range, 34–77).

The preoperative diagnosis was osteoarthritis in all the hips replaced except for three with Müller replacement which had rheumatoid arthritis.

The operations were performed by the techniques described by the originators of the prostheses (Charnley & Ferreira 1964, Müller 1970). The procedures were performed by one of two ex-

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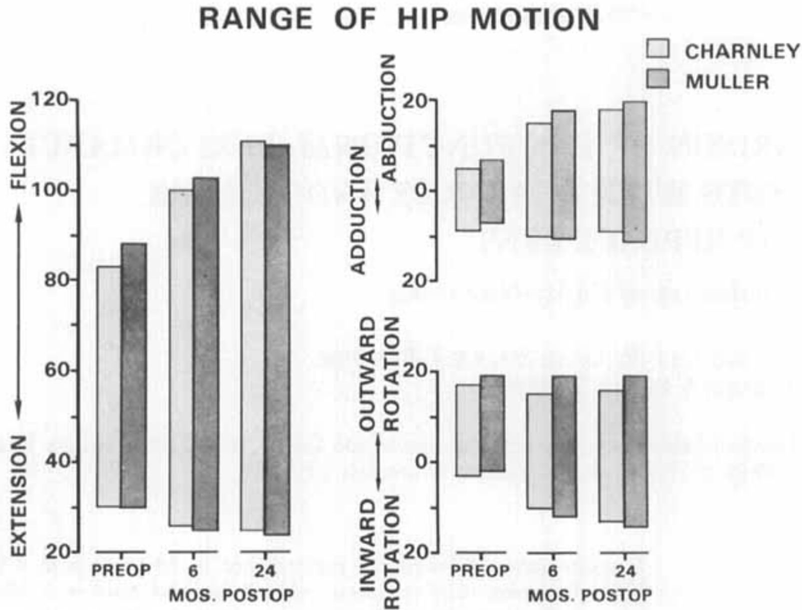

Figure 1. Bar graphs showing the mean ranges of hip motion before, and 6 and 24 months after total hip replacement for 35 hips with Charnley replacement and 54 hips with Müller replacement.

perienced hip surgeons, thus minimizing differences in surgical technique within a given replacement group. Trochanteric osteotomies were performed in all patients.

Range of hip motion was measured by standard methods (American Academy of Orthopaedic Surgeons 1965). The strength of the hip abductor and adductor muscles during maximum isometric contraction was measured as the product of a force recorded by a transducer attached to the lower limb and the distance between the transducer attachment and the center of the hip joint (Murray & Sepic 1968). The average amount of weight supported under the right and left feet during 1-minute periods of quiet standing was monitored with dual force platforms (Murray & Peterson 1973) and measurements of multiple simultaneous displacement patterns of free-speed and fast walking were made from photographs obtained with interrupted-light photography (Murray et al. 1964). The measurements of walking performance reported in this study were made while the patients walked without support. In addition, the force applied to canes or crutches was measured in those patients who routinely used assistive devices to walk outdoor distances of approximately 150 meters (Seireg et al. 1968).

A multiple classification analysis of variance was used to test the significance of the differences in functional performance between the pre- and postoperative testing sessions and also between the patient groups.

RESULTS

Preoperatively both replacement groups had similar deficits in the measurements of various components of function. The patients had limited hip motion, particularly flexion, extension, abduction and inward rotation (Figure 1), and they had profound weakness of the hip abductor and adductor muscles (Figure 2). During quiet standing most of the patients bore substantially less weight on the limb to be operated than on the contralateral limb (Table 1). Most of the patients used assistive devices during walking and the average amount of force applied during the stance phase of the involved limb varied considerably among the patients (range, 1 to 38 kg). Their gait abnormalities were characteristic of the antalgic limp of patients with hip pain (Murray et al. 1971). For example, their walking speeds were subnormal as a result of both slower cadences and shorter

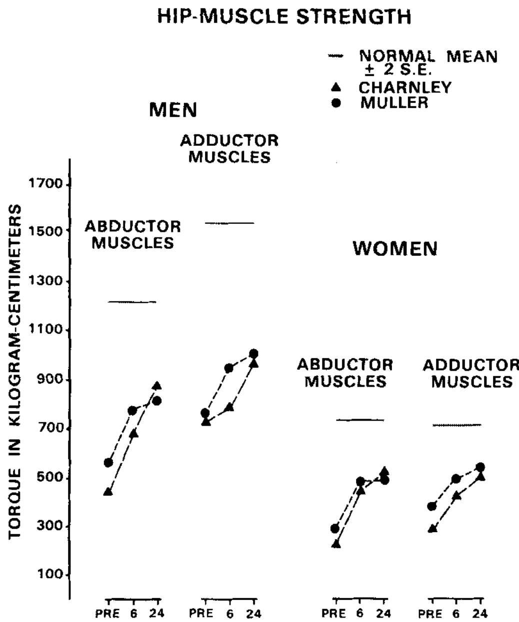

Figure 2. Mean maximum isometric strength of the hip abductor and adductor muscles before, and 6 and 24 months after total hip replacement for 35 hips with Charnley and 54 hips with Müller replacement. The horizontal line and shaded area it bisects represents the mean ±2 standard errors for normal men and women (Murray & Sepic 1968). At the preoperative test session the women to have Müller replacement had significantly higher adductor torque than the women to have Charnley replacement (P < 0.05).

step lengths (Figure 3). The successive step lengths were uneven with the shorter step usually occurring when the sound limb was forward and the affected limb was behind. The amount of flexion-extension used at the affected hip was very limited during walking (Figure 3), mainly because of failure to extend the hip, and this limited use of hip extension was related to the amount of hip *flexion* contracture. The single-limb-support phase of the operative limb was short compared to that of the contralateral limb (Table 3). The patients had excessive lateral lurching (Figure 3) and their forward motion was characterized by a stop-start type of limp which was quantitated by making a ratio of forward velocity during single-limb-support on the untreated limb to that on the operative limb. This velocity index was usually less than 1.00 because patients with unilateral hip pain typically move forward faster over the painful limb than the sound limb (Table 2). In addition, the vertical excursions of the head of the patients were of lesser amplitude during the supportive phase on the operative limb than during the supportive phase on the contralateral limb (Table 3). Preoperatively, the gait deviations from normal were typically more pronounced during fast walking than free-speed walking.

Two years after surgery there was significant improvement in all of the parameters of function measured for both replacement groups ($P < 0.01$) except for motions into hip adduction and inward rotation.

Ranges of normal variability have been established for hip-muscle strength, weight-bearing ability and each of the components of walking performance; these are indicated in the graphs and tables. On an average, the largest improvement toward normal function for both replacement groups consistently occurred during the first 6 postoperative months, but additional improvement occurred between 6 months and 2 years, postoperatively.

*Table 1. Percent body weight borne on limb with total hip replacement**

Group	Number of patients	Preop.	6 months postop.	24 months postop.
Charnley	21	33 ± 1.7	42 ± 1.6	48 ± 2.0
Müller	33	35 ± 2.2	44 ± 1.0	46 ± 1.1
Normal				50 ± 1.4

* Mean values and one standard error for patients with unilateral hip replacement only.

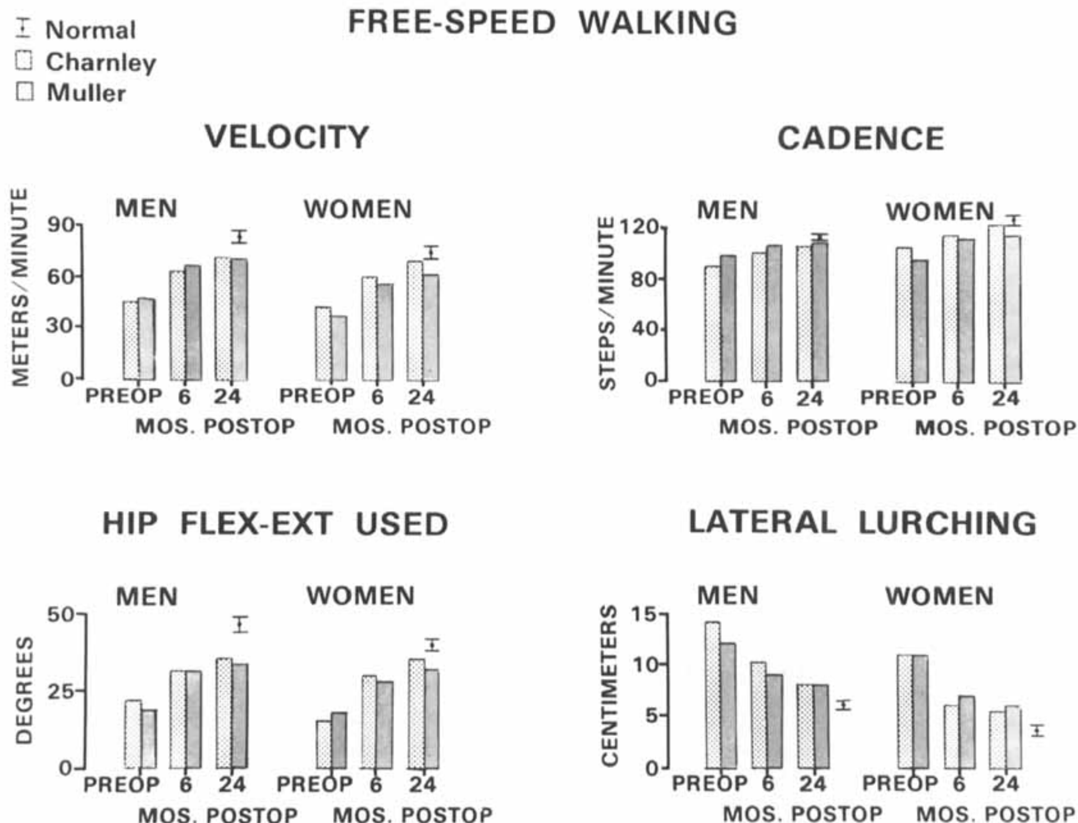

Figure 3. Bar graphs showing mean velocity, cadence, hip flexion-extension used, and lateral lurching during free-speed walking for 29 patients with Charnley replacement and 46 patients with Müller replacement. For hip flexion-extension, both hips of those with bilateral replacement were included in the mean values. The dots indicate means, and the vertical lines 2 standard errors above and below the mean for normal men (Murray et al. 1969) and normal women (Murray et al. 1970). At the pre-operative test session the women scheduled for Müller replacement used significantly more hip flexion-extension than the women scheduled for Charnley replacement (P < 0.05).

*Table 2. Velocity index**

Group	Number of patients	Preop.		6 months postop.		24 months postop.	
		Mean	Range	Mean	Range	Mean	Range
Charnley	21	0.81	(0.43–1.01)	0.92	(0.70–1.01)	0.96	(0.85–1.04)
Müller	33	0.78	(0.34–0.95)	0.93	(0.80–1.00)	0.97	(0.86–1.02)
Normal						1.00	(0.94–1.07)

* Velocity index is a ratio of the patient's forward velocity during single-limb-support on the untreated limb to his velocity during single-limb-support on the treated limb. Patients with bilateral hip replacement have been excluded.

Both *groups* reached or were remarkably close to reaching the lower limits of normal variability in cadence, weight-bearing ability and velocity index. It was not unusual, however, to find several *individuals* within each group who had normal performance in other components of function such as velocity for free-speed walking, and equality factors such as single-limb-support ratios and differences in successive step lengths. The components of function for which the groups were most abnormal 2 years after surgery included: hip muscle strength, velocity during fast walking, lateral lurching and hip flexion-extension used during both walking speeds.

Comparison of groups with Charnley and Müller replacements

Ratings of hip pain 2 years after surgery (Lazansky 1967) were slightly more favorable for the group with Charnley than for the group with Müller replacement. Sixty-six per cent of those with Charnley and 48 per cent of those with Müller replacement reported no pain. Approximately 24 per cent in each group reported slight pain on initiating motion which decreased with activity. Eleven per cent of those with Charnley and 28 per cent of those with Müller replacement reported pain which was initiated by activity and disappeared with rest. None of the patients had severe pain.

Postoperatively, improvement in the use of assistive devices was dramatic for most patients. Sixty-six per cent of the patients in each replacement group discontinued using assistive devices during the 2-year period. Eight patients with Müller and one with Charnley replacement were still using a cane 2 years after surgery. All but one of these were applying less force than preoperatively and their average forces ranged from 2 to 12 kg.

Two years after surgery no statistically significant differences were found between the groups with Müller and Charnley replacement in measurements of walking performance and weight supported between the feet during quiet standing. In the strength tests, the men and women with Charnley replacement had more improvement from before to 2 years after surgery in hip abductor-muscle torque than the men and women with Müller

Table 3. Inequality in successive single-limb-support times, step lengths and vertical excursions of the head

Group	Preop. Mean ± 1 s.e.	6 months postop. Mean ± 1 s.e.	24 months postop. Mean ± 1 s.e.
	*Ratio of successive SLS times**		
Charnley	0.86 ± 0.03	0.96 ± 0.03	1.02 ± 0.03
Müller	0.83 ± 0.03	0.95 ± 0.02	0.96 ± 0.02
Normal			1.00 ± 0.01
	Average difference in successive step lengths (cm)		
Charnley	6.7 ± 1.3	3.9 ± 0.6	3.5 ± 0.5
Müller	5.8 ± 0.8	4.3 ± 0.5	3.2 ± 0.4
Normal			2.9 ± 0.3
	Average difference in successive vertical excursions of the head (cm)		
Charnley	1.3 ± 0.3	0.5 ± 0.2	0.4 ± 0.1
Müller	1.2 ± 0.2	0.7 ± 0.1	0.6 ± 0.1
Normal			0.0 ± 0.1

* Operative single-limb-support time divided by opposite single-limb-support time.

replacement, but the difference was statistically significant only for the women ($P < 0.05$). In range of hip motion there were no statistically significant differences between the groups before or after surgery with two exceptions: the group with Müller replacement had more abduction 6 months after surgery and more outward rotation at both postoperative tests ($P < 0.05$).

DISCUSSION

When the surgeon is choosing the specific type of total hip prosthesis he wishes to use, his considerations include many things such as the incidence of component breakage, loosening, infection and wear, but the question still remains: Does one type of prosthesis allow the patient to function better than another type? In order to answer this question, we evaluated multiple factors which we feel are sensitive indicators of functional performance. Hip-muscle strength, hip motion and weight-bearing ability affect walking performance as well as the performance of many common daily activities. Slow walking speed or the need to apply high loads to assistive devices are frequently limiting factors in terms of the patient's rehabilitation or employment potential. Lateral lurching, irregularities in vertical excursions of the head and trunk, and stop-start type of forward progression were measured because these gait abnormalities require excessive mechanical energy expenditure by the patient. Lastly, we evaluated hip flexion-extension used during walking because restricted motion of the hip usually contributes to short and unequal successive step lengths which, in turn, contribute to a slow and irregular mode of progression.

We anticipated seeing differences in hip abductor muscle strength and lateral lurching between the two replacement groups since the Charnley femoral component, with its smaller diameter head, would allow a more medial position of the center of rotation. Indeed, the group with Charnley replacement did have slightly greater improvement from before to 2 years after surgery than the group with Müller replacement in hip abductor muscle strength, lateral lurching and also hip flexion. In these components, the group with Charnley replacement had lower preoperative levels and reached slightly higher postoperative levels than the group with Müller replacement. The small differences between the groups in abductor muscle strength, lateral lurching and hip flexion 2 years after surgery were not statistically significant, nor were they large enough to conceivably affect overall patient performance.

There were, in fact, no statistically significant differences in the average levels of function reached by the groups with Charnley and Müller replacements 2 years after surgery for *any* component of function except outward rotation of the hip. Both groups had remarkable and statistically significant amounts of improvement, although neither group was within the limits of normal variability for normal subjects in comparable age groups for most of the components of function. Even though the average age of these patients was over 60, when one might conceivably find small declines in function, we were pleased to find continued postoperative improvement throughout the 2-year test period.

It is hoped that these quantitative measurements on the nature, rate and extent of change in functional performance will be useful in comparing the performance of patients with hip replacements over a longer postoperative period and that these measurements will serve as baselines for comparing the results following other reconstructive procedures.

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