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Functional Recovery of Muscles After Minimally Invasive Total Hip Arthroplasty

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Abstract

Whether mini-incision total hip arthroplasty is associated with accelerated postoperative recovery is a subject of considerable controversy. A study was conducted to compare objective outcomes using gait analysis as a measure for recovery of function in patients treated with three different minimally invasive surgical approaches and the traditional posterior approach. Sixty-nine patients underwent instrumented gait analysis at self-selected and fast velocities preoperatively and at 6 weeks and 3 months postoperatively. Four surgical groups were studied—30 treated with posterior mini-incisions, 11 anterolateral, 10 anterior Judet, and 18 traditional posterior long incisions. Overall, gait velocity increased slightly at 6 weeks and significantly at 3 months. However, there were no significant differences between groups for velocity, cadence, stride length, single-limb support time, or double-limb support time at 6 weeks or 3 months postoperatively. These data indicate that patients undergoing total hip arthroplasty with any of these surgical approaches recover muscle function, as measured by gait analysis, to preoperative levels within 6 weeks postoperatively. No advantage was shown with the use of any of the three different small-incision approaches. This finding suggests that the amount of muscle, or the particular muscle cut, does not have a significant effect on the recovery of postoperative gait function.

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Minimally invasive surgery (MIS) for total hip arthroplasty has been described as a reduction in surgical incision size to 10 cm or less and as a muscle-sparing procedure. A number of studies have documented the technical success and safety of various minimally invasive operations performed by experienced surgeons and have found outcomes equivalent to those achieved with the standard incision technique previously used by that surgeon or a group of surgeons.[1-8] Two studies have reported improvements in either postoperative limp or stair-climbing ability in patients who have undergone MIS.[9,10] There are limited objective data comparing the recovery of gait function in patients who have undergone MIS and those who have been treated with a traditional-length incision.[11] Therefore, this study compared the recovery of temporospatial gait characteristics following total hip arthroplasty in each of four surgical groups: those treated with a long posterior traditional incision, posterior mini-incision, anterolateral mini-incision, and anterior Judet MIS performed on a special table. The hypothesis of this study was that patients treated with the small-incision operations would perform better than those treated with the traditional posterior incision with early (6 weeks and 3 months) objective gait-analysis testing. The basis of this hypothesis

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Table 1
Patient Demographics (Mean ± Standard Error)

	Anterolateral MIS (n = 11)	Anterior MIS (n = 10)	Posterior Standard (n = 18)	Posterior MIS (n = 30)
Age (years)	55.0 ± 2.0	64.0 ± 2.0	61.0 ± 2.0	64.0 ± 1.0[†‡]
Body mass index	28.9 ± 1.2	27.8 ± 1.1	29.8 ± 1.0	26.1 ± 0.5[*]
Preoperative self-selected velocity (m/min)	60.6 ± 2.4	62.8 ± 3.4	56.9 ± 2.1	62.8 ± 1.3
Preoperative fast velocity (m/min)	81.7 ± 5.3	70.6 ± 2.6[†§]	69.9 ± 4.2[†‖]	80.4 ± 3.9

MIS = minimally invasive surgery
[*] Significantly different from posterior standard (P = 0.019)
[†] Significantly different from anterolateral MIS
[‡] P = 0.004
[§] P = 0.016
[‖] P = 0.040

was that muscle function would improve more quickly and be stronger with small-incision surgery, and this would be reflected in the objective gait analysis.

Methods

Sixty-nine patients were enrolled in the study at the time of their preoperative clinical visit for total hip arthroplasty. Informed consent was obtained from each patient in accordance with the local ethics committee guidelines. Demographics of age and body mass index, plus the preoperative self-selected and fast gait velocities, are shown in Table 1. Patients in the posterior MIS group were on average 9 years older than the anterolateral MIS group and 9.7 kg lighter than the posterior long-incision surgical group.

The traditional posterior long incision was performed in 18 patients, the posterior mini-incision was performed in 30 patients, the anterolateral mini-incision was done in 11 patients, and the "no muscle cut" anterior Judet MIS using a special traction table was done in 10 patients.[12,13] The participating surgeons had familiarity with the approach used.

Gait analysis was performed at two different walking velocities: a self-selected speed that felt most comfortable and a "fast" gait speed at which patients were asked to walk as rapidly as could be tolerated without discomfort. Patients were allowed to practice each velocity until they were comfortable with the device and the instructions. Three representative trials were obtained for each velocity and averaged for final analysis. Gait data were collected using a battery-operated instrumented device, the IDEEA (MiniSun LLC, Fresno, CA) physical activity monitor with leads taped to the feet and legs that recorded data that were analyzed using computer software (Figure 1). The device was simple and convenient enough to be used in the office hallway. Data were collected at three times: preoperatively, and at 6 weeks and 3 months postoperatively. Stride characteristics that were measured included gait velocity, cadence, stride length, single-limb support time, and double-limb support time. Average values were compared for each patient at each time point (preoperatively, 6 weeks postoperatively, and 3 months postoperatively).

Statistics

To compare the recovery of these parameters between surgical groups, repeated measures analyses of covariance and post hoc tests with corrections for multiple comparisons were used. Statistical computations were made with SPSS software (SPSS version 11.0, SPSS Inc., Chicago, IL) using a significance threshold of $\alpha = 0.05$. Data are presented as mean ± standard deviation, unless otherwise noted.

Results

Preliminary data analysis indicated that patient age negatively correlated with self-selected gait velocity at 6 weeks ($r^2 = 0.048$, $P = 0.022$) and at 3 months ($r^2 = 0.113$, $P < 0.001$); likewise, preoperative self-selected gait velocity correlated positively to the 6-week result ($r^2 = 0.280$, $P < 0.001$) and the 3-month result ($r^2 = 0.360$, $P < 0.001$) (Figure 2). Although there were no obvious differences in self-selected or fast preoperative gait velocities between groups, these data indicated that preoperative temporospatial gait parameters should be included in the analyses as covariates. This step simply allows surgical groups to be

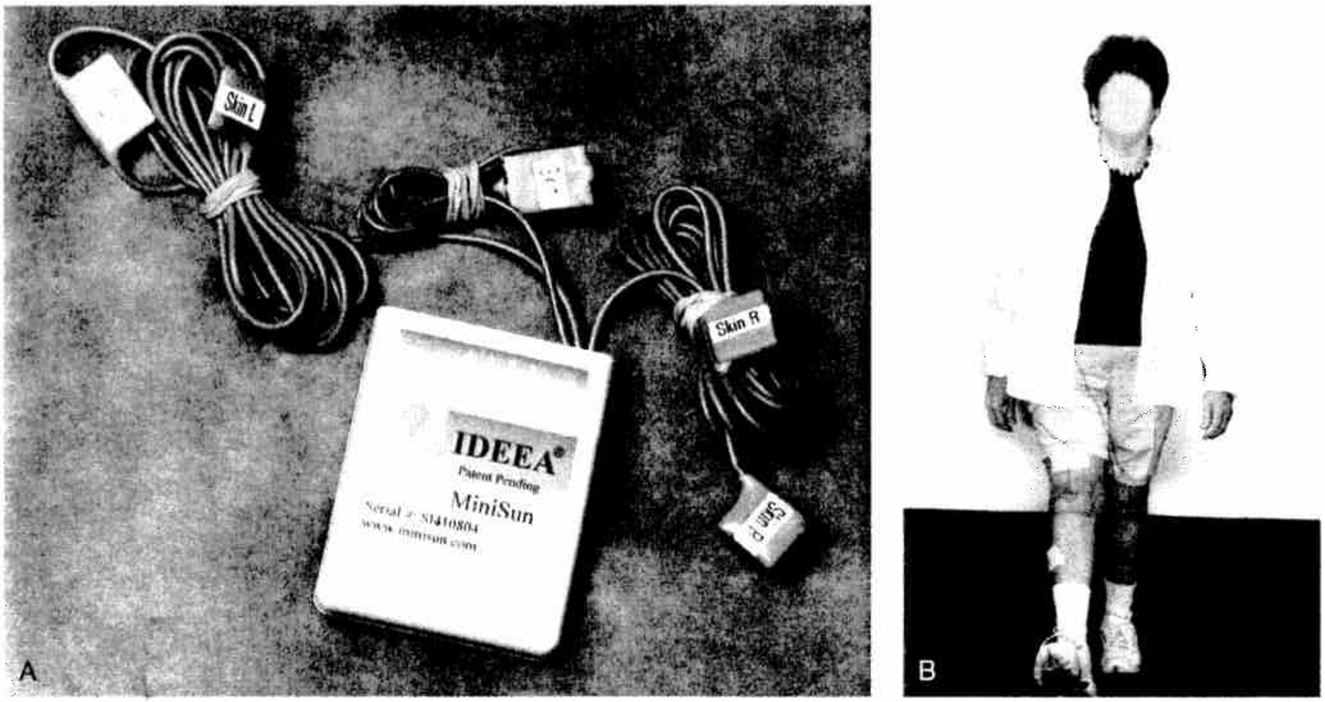

Figure 1 **A,** The IDEEA physical activity monitor is a portable device that was used for instrumented gait analysis. Stride characteristic data were collected from this device and analyzed with computer software. **B,** Patient walking in clinic, instrumented with leads attached. No special gait laboratory was necessary.

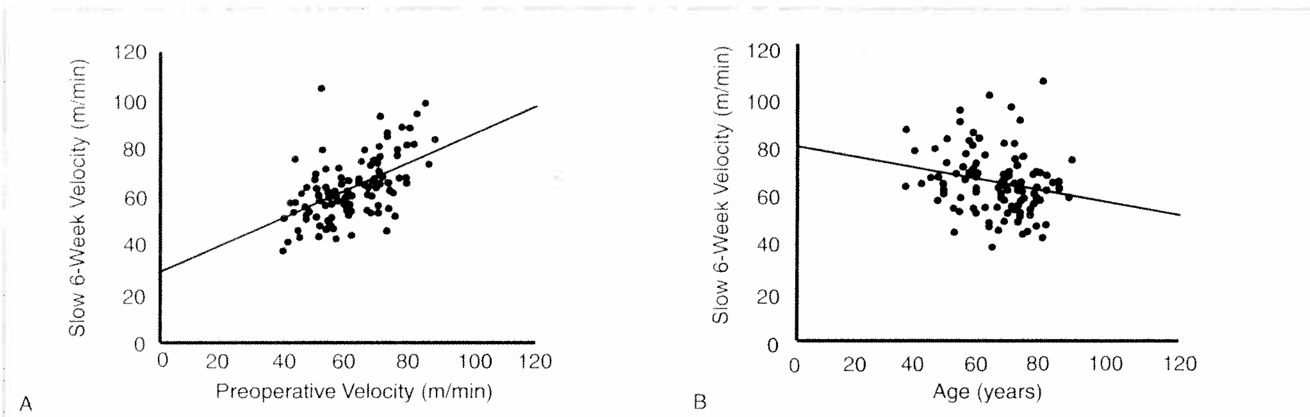

Figure 2 **A,** Graph comparing preoperative and 6-week self-selected gait velocity. **B,** Age correlates negatively with 6-week velocity (r^2 = 0.0.048, P = 0.022) and 3-month velocity (r^2 = 0.113, P = 0.001).

compared without the confounding effect of preoperative gait velocity.

Self-selected and "fast" gait velocities improved significantly over preoperative values by 3 months (Tables 2 and 3). At the patient's self-selected pace, velocity (in m/min) increased from 60.1 ± 1.42 to 61.5 ± 1.4 at 6 weeks, and to 68.8 ± 1.2 at 3 months ($P < 0.001$), a 5% and 16% improvement, respectively. When patients were asked to walk fast, velocity increased from 77.2 ± 1.5 to 78.3 ± 1.9 at 6 weeks and to 84.9 ± 2.0 at 3 months ($P < 0.05$), a 10% improvement. These improvements were the product of increases in cadence (steps/min) and stride length in all groups.

At 6 weeks and 3 months, there were no significant differences between groups for velocity (P = 0.243 and 0.61), cadence (P = 0.18 and 0.19), stride length (P = 0.71 and

Table 2
Six-Week Temporospatial Gait Characteristics (Mean ± Standard Deviation)

	Anterolateral MIS	Anterior MIS	Posterior Standard	Posterior MIS
Self-selected velocity (m/min)	62.30 ± 6.60	54.40 ± 9.80	61.40 ± 13.00	66.50 ± 13.50
Cadence (steps/min)	99.00 ± 16.00	100.00 ± 14.00	106.00 ± 20.00	108.00 ± 12.00
Stride length (m)	1.26 ± 0.30	1.04 ± 0.11	1.16 ± 0.26	1.23 ± 0.30
Single support (msec)	393.50 ± 37.00	413.70 ± 32.80	393.20 ± 36.60	404.20 ± 27.00
Double support (msec)	139.20 ± 28.40	150.00 ± 47.50	130.50 ± 58.50	129.10 ± 38.90
Fast velocity (m/min)	80.00 ± 8.60	72.60 ± 7.10	71.80 ± 18.40	77.10 ± 14.50
Cadence (steps/min)	121.00 ± 11.00	101.00 ± 14.00	117.00 ± 21.00	119.00 ± 12.00
Stride length (m)	1.29 ± 0.14	1.10 ± 1.16	1.24 ± 0.38	1.29 ± 0.20
Single support (msec)	365.70 ± 31.90	393.10 ± 30.00*	363.60 ± 48.40	384.20 ± 31.00†
Double support (msec)	91.60 ± 15.50	115.60 ± 35.40	110.90 ± 39.30	102.50 ± 30.70

MIS = minimally invasive surgery
*Significantly different from posterior standard ($P = 0.009$)
†Significantly different from posterior standard ($P = 0.013$).

Table 3
Three-Month Temporospatial Gait Characteristics (Mean ± Standard Deviation)

	Anterolateral MIS	Anterior MIS	Posterior Standard	Posterior MIS
Self-selected velocity (m/min)	71.50 ± 7.90	63.80 ± 10.80	69.10 ± 11.90	69.20 ± 11.10
Cadence (steps/min)	112.00 ± 12.00	108.00 ± 11.00	116.00 ± 14.00	114.00 ± 10.00
Stride length (m)	1.24 ± 0.10	1.16 ± 0.18	1.18 ± 0.13	1.23 ± 0.19
Single support (msec)	387.80 ± 32.10	396.20 ± 30.30	380.10 ± 34.50	401.70 ± 28.90*
Double support (msec)	121.10 ± 25.30	128.10 ± 34.00	124.70 ± 49.90	115.80 ± 34.30
Fast velocity (m/min)	91.80 ± 14.80	82.70 ± 19.60	81.80 ± 19.80	82.70 ± 13.80
Cadence (steps/min)	133.00 ± 16.00	119.00 ± 11.00	128.00 ± 18.00	126.00 ± 10.00
Stride length (m)	1.36 ± 0.14	1.20 ± 00.12	1.27 ± 0.18	1.33 ± 0.20
Single support (msec)	348.70 ± 32.90	374.90 ± 26.30	364.80 ± 38.40	380.90 ± 31.60†
Double support (msec)	85.40 ± 15.40	102.20 ± 25.30	101.80 ± 45.80	91.30 ± 30.20

MIS = minimally invasive surgery
*Significantly different from posterior standard ($P = 0.003$).
†Significantly different from posterior standard ($P = 0.015$).

0.70), single-limb support time ($P =$ 0.50 and 0.40), or double-limb support time ($P = 0.35$ and 0.418). Careful inspection of each time point showed that single-limb support time was significantly shorter in the posterior standard-incision group than the posterior MIS group at 3 months at self-selected gait speeds, and at 6 weeks and 3 months during fast gait (Tables 2 and 3). However, it has been shown that single-limb support time is negatively correlated with gait velocity.[14] This concept makes intuitive sense because as velocity increases, the time one spends in stance declines. When single-limb support time was normalized by walking velocity at the same time point, these differences were no longer apparent, suggesting that the differences were likely caused by small velocity differences between groups at 3 months.

Discussion

The authors' hypothesis—that patients treated using small incision operations would perform better with objective gait analysis and therefore had better muscle function than did those treated with a posterior long incision—was not proved. Furthermore, the operations that had no muscle cut did not perform better than the small-incision operations that did have muscle cut. The results showed that the most important predictor of postoperative gait function is preoperative gait function, and age is negatively correlated with gait velocity. As patient age increased, walking velocity declined; this finding is consistent with aging-associated velocity changes in the normal population.[14] The absence of influence of small-incision surgery on the results of gait analysis is an important finding because MIS, particularly the approaches that do not cut muscles, were expected to promote more rapid gait recovery.[1,13,15] However, more rapid recovery is mainly related to how well the patient walked preoperatively and to the patient's age.

The use of a small incision, and whether or not muscle was cut with the approach, seems to have no influence on recovery of gait at 6 weeks and 3 months postoperatively.

The first limitation of this study is that it is underpowered. For the data presented in this report, the study would have required at least 162 patients in each group to reach a power of 80%. To account for this weakness, the authors considered as many confounding factors as possible (age, body mass index, and preoperative gait velocity). The second weakness of this study is that the demographics of the group were not statistically equivalent. However, by correlating postoperative gait function to preoperative gait function for each patient, this difference in demographics did not influence the study results.

Patients' self-selected walking velocity at 6 weeks postoperatively was similar to their preoperative velocity; only by 3 months did they walk 16% faster (on average) than preoperatively. At 3 months, all groups could walk at normal gait velocity when they used their fast walk (normal gait velocity is 80 m/min). These patients achieved the ability to walk at a normal gait velocity with their fast walk more rapidly than did patients the authors had previously studied.[16] These data support early aggressive postoperative mobilization and walking for postoperative therapy.

Although several studies have reported early postoperative recovery with small-incision total hip replacement, such as improvements in postoperative limp and stair-climbing ability,[1,2,9,10] the objective data of this study do not support early improvements in gait. Bennett and associates[11] reported no significant improvements in gait with the posterior MIS approach. It has been argued that anterior and posterior MIS approaches have different effects on postoperative recovery; the data presented here do not support these claims. Patients improved even with the anterolateral approach, which divides the gluteus medius muscle. Patients with a "no muscle cut" anterior approach had no better results than any other patients, although with a sufficient patient sample the finding of a better single-limb stance time for these patients than those with the anterolateral approach may be confirmed. The findings of a better single-limb stance time in patients treated with a posterior mini-incision compared with those treated with a posterior long incision approach also might be confirmed with a larger patient sample size. The statistically better single-limb stance time for the direct anterior approach and the posterior mini-incision was not present when corrected for gait velocity.

The absence of significant differences in postoperative gait function between surgical approach groups most likely is explained by muscle physiology and cadaveric muscle-damage studies.[17-19] Repair of muscle damage by elective surgery has already occurred by 6 weeks postoperatively. Muscle undergoes four phases of healing: degeneration, inflammation (these first two occur in the first few days after injury), regeneration, and fibrosis. The regeneration process can peak as early as 2 weeks after injury, and formation of scar tissue begins between the second and third weeks after injury.[17] The regeneration of muscle is directly related to the amount of scar tissue formed, which is related to the amount of damage. The large skeletal muscles, such as those around the hip, contain up to 1,000 myofibers per single motor unit, compared with muscles with coordinated movements such as extraocular muscles, which have 10 myofibers per motor unit.[17] Large skeletal muscles can sustain more damage before substantial impact on their function. The amount of damage to muscles is essentially the same with all the MIS approaches studied (direct anterior approach, posterior mini approach, and two-incision approach) in the cadaver studies of Mardones and associates[18] and Meneghini and associates.[19] The comparison of muscle damage between the small incisions and the posterior long incision was not studied in the cadaveric model. The healing of bone also influences gait, and bone injury is essentially the same regardless of the surgical approach. Bone healing is dependent on osteon remodeling time, which averages 6 months, with no known factors that can accelerate it.[20,21] The rapid healing of muscle, and the prolonged healing of bone, diminish the influence of the incision size on the physiologic healing of tissues after total hip arthroplasty.

The most influential recovery factor that may be responsible for improved function for patients treated with a small incision may be the patient's mental response to the incision.[22] Psychological studies of patients showed that those treated with either a posterior mini-incision or a posterior long incision believed that the small incision contributed to improved function at 6 weeks postoperatively. Increased confidence in patients who had a small incision could easily affect their daily functional activities and their attitude toward their functional recovery. Improvements in patient education, anesthesia, and pain management also contribute to earlier recovery.[23,24] These effects would not be factors in this study because all patients were treated with similar education and pain management methods.

Summary

This gait analysis study showed that the muscle injury associated with the four different approaches studied is not clinically important with respect to gait function by 6 weeks postoperatively. This finding suggests that muscle injury may not play a significant role and is not a rate-limiting factor in recovery following total hip replacement. The factors most important for the rapid recovery of patients postoperatively may be their psychological satisfaction with the operation as well as the anesthesia and pain management treatment used.[22,23]

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