Hip Resurfacing Does Not Improve Proprioception Compared With THA

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Abstract

Background Proposed benefits of total hip resurfacing arthroplasty over total hip arthroplasty (THA) include better proprioception, but this has not been rigorously tested or validated.

Questions/purposes Our purpose was to apply an advanced testing device that objectively quantifies dynamic postural stability to determine if total hip resurfacing is associated with improved proprioception compared with standard or large-head THA.

Methods Three groups of 25 patients (total hip resurfacing, THA femoral head > 32 mm, THA femoral head ≤ 32 mm) and a matched control group were recruited. All participants had UCLA scores ≥ 5 and Harris hip scores ≥ 90 at the time of testing. Testing was conducted using a commercially available device that uses a multidirectional, powered platform to measure deviations of the center of mass and consisted of trials with both double- and single-limb support.

Results Double-limb testing showed no differences between groups. In single-limb testing, the operative side

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performed better in patients who had undergone total hip resurfacing versus THA, but this difference disappeared when the operative side was normalized to the nonoperative side. When compared with control subjects who had not had arthroplasty, both operative and nonoperative sides showed significantly worse proprioception for all arthroplasty cohorts, suggesting that decreased proprioception is associated with arthritis of the hip in young adults.

Conclusions Total hip resurfacing arthroplasty did not result in improved proprioception compared with THA. These results tend to refute the concept that improved proprioception is a rationale for selecting total hip resurfacing over THA in young patients.

Level of Evidence Level III, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

As patients seek higher function after hip arthroplasty procedures [3, 10], differences in joint performance between total hip resurfacing arthroplasty and THA have started to affect surgeons' decision-making [15].

Proprioception is a complex sense requiring inputs from the somatosensory, vestibular, visual, central nervous, neuromuscular, and musculoskeletal systems. Attempts to quantify the ability to assess joint position of the hip have been present almost since the inception of THA [9]. Recent attempts to quantify proprioception have relied on gait studies [14] and measurement of center of mass displacement during quiet standing [17]. Although these attempts have led to interesting findings, the techniques used in these studies seem relatively simple compared with the complex neuromuscular functions involved with proprioception.

There is no gold standard for measuring proprioception. Recently, advanced techniques have come into use in rehabilitation research that allow for the objective measurement of multiple neurological inputs that more closely tracks proprioception. These approaches rely on the concept that trunk control during dynamic posturography is the best surrogate for measuring proprioception. This conclusion has been validated in patients with balance disorders [1] and also shows good correlation with other proprioception measures including the NeuroCom sensory organization test [4]. To measure trunk control, an ultrasonic sensor is placed at the lumbosacral junction to measure perturbations in the center of mass and this has been shown to be accurate compared with high-speed camera motion analysis [6].

The purported advantage of improved proprioception with total hip resurfacing arthroplasty was believed to be a result of the preservation of the femoral head and neck as well as the attached soft tissue and the maintenance of a

head size similar to the native femoral head. With newer metal-on-metal THA designs, comparable femoral head sizes have been achieved and thus potentially would have the same proprioceptive benefit seen in total hip resurfacing arthroplasty. This comparison has been made with quiet standing [17] but not with demanding test protocols more reflective of the high activities anticipated for total hip resurfacing arthroplasty in young, active patients. Prior studies also only used double-limb standing protocols that are more prone to selection bias. If patients are preselected for a surgical procedure who have better balance and coordination (proprioception) preoperatively, they may perform better postoperatively as a result of this inherent bias. By incorporating single-limb testing of the operative and nonoperative limbs, every patient can serve as an internal control, and the operative limb test result can be normalized versus the nonoperative side of each patient.

We therefore asked whether there would be differences in double- or single-limb proprioception among patients who had undergone total hip resurfacing arthroplasty, THA with a standard diameter femoral head (≤ 32 mm), THA with a large-diameter femoral head (> 32 mm), and healthy control subjects. The hypothesis that we tested was that patients who had undergone successful total hip resurfacing arthroplasty would have improved proprioception compared with THA and that among patients undergoing THA, large-head THA would be associated with more normal proprioception than standard THA.

Patients and Methods

After institutional review board approval of our study protocol, patient recruitment started both in the outpatient clinics and through screening of an institutional total joint registry. To be eligible for the study, patients needed to meet the following criteria: they had undergone unilateral primary hip reconstruction between 1 and 5 years prior; aged 18 to 60 years; current UCLA activity score of 5 or higher (out of 10, with a score of 5 indicating "sometimes participates in moderate activities such as swimming, or could do unlimited housework or shopping"); current modified Harris hip score (HHS) of 90 or higher (out of 100) [5]; and a body mass index (BMI) of 35 kg/m² or less. Patients were excluded from the study if they had evidence of confounding pathology that may disrupt postural stability, including symptomatic osteoarthritis of other joints in the lower extremity (including the contralateral hip) or the spine, neuromuscular disease, nonorthopaedic balance disturbances, previous amputation, or diabetes with documented peripheral neuropathy. Further exclusion criteria included the use of assistive devices within the last 6 months, significant medical comorbidities that limit

physical activity, pain in the operative joint, limp, or pregnancy. A control group was also established that adhered to the same inclusion and exclusion criteria save for the fact that they did not undergo any previous hip reconstructive procedure; this control group was matched for UCLA activity level and average age (within 5 years) to the treatment groups but was not screened clinically or radiographically for the presence of arthritis.

A power analysis was performed before study initiation. At present, there are no data using this machine in a similar setting for a patient population. Thus, calculations were performed using estimates of variability derived from healthy control subjects [4]. Computations were performed to determine the magnitude of the between-group difference that can be detected with the proposed sample sizes at the 0.05 level of significance using two-sided unpaired t-tests. Two comments about this computation are in order. First, we have estimated effects using t-tests instead of the analysis of variance models we will use in practice because we have no way to estimate variability in the patient population before study initiation. Second, this will be the first application of this device in a physical therapy setting with a goal to provide preliminary data for use in the design of future trials.

Accordingly, the final cohort included 100 patients, which was made up of three groups of 25 patients (total hip resurfacing arthroplasty, THA with femoral head > 32 mm, and THA with femoral head ≤ 32 mm) and 25 in the matched control group of normal subjects. Ninety-three patients were white (93%) and 62 were male (62%) with a mean age of 52 years. All four groups were comparable in relation to age, BMI, UCLA score, modified HHS, dominant limb, and years out from surgery (Table 1). The total hip resurfacing arthroplasty group had a higher percentage of males enrolled as a result of the indications for the procedure during the study period. The self-reported dominant leg was recorded for each subject (to ascertain

limb dominance, patients were asked which leg they would use to kick a soccer ball).

Testing was conducted on the PROPRIO 5000 machine (Perry Dynamics, Decatur, IL, USA), a commercially available device that quantifies dynamic postural stability. It uses a multidirectional, powered platform that measures deviations of the center of mass in 6 degrees of freedom every quarter second (Fig. 1A). Patients were placed on the platform with their feet shoulder width apart, knees slightly flexed, and center of mass centered over the center of the board by a single examiner (Fig. 1B). A 6-inch piece of rope was placed in the patients' hands and they were instructed to hold this in front of them to remove the effect of the upper extremities on balance (Fig. 2). An ultrasonic sensor was placed at the L5-S1 junction and this transmitted the patients' position in space. To familiarize the patients with the testing protocol, a brief learning module was performed where the patients could see on the computer monitor where their centers of mass were and how they changed with alterations in the platform.

Formal testing began with three 1-minute tests with double-limb standing. Given the potential for selection bias with possibly more athletic patients seeking out total hip resurfacing arthroplasty so as to continue their athletic endeavors, single-limb testing was also performed. After the double-limb testing was complete, three 1-minute tests in each single-limb stance were performed with the side being tested first being randomly assigned.

Each trial finished when one of the following criteria was met: 1 minute had elapsed, the patient exceeded 3 inches of movement in 0.25 seconds, the patient moved greater than 5 inches from the starting point, the patient let go of the rope, the patient moved their feet, or the patient asked to stop.

The PROPRIO 5000 machine captures data at quarter-second intervals in six planes: AP, lateral, up/down, flexion/extension, lateral flexion, and rotation. The

Table 1. Demographics of the study groups

Patient factor	Healthy control subjects (n = 25)	Standard femoral head THA (n = 25)	Large femoral head THA (n = 25)	Total hip resurfacing arthroplasty (n = 25)
Age (years)	48.7 ± 6.6 (37.2–60.3)	53.6 ± 5.0 (39.0–59.7)	53.3 ± 6.3 (33.5–60.9)	52.9 ± 6.0 (30.7–59.5)
Sex (male/female)	15/10	12/13	13/12	22/3
Dominant leg (right/left)	23/2	22/3	23/2	24/1
Body mass index (kg/m ²)	25.9 ± 4.4 (20.4–34.2)	26.6 ± 3.2 (18.2–31.5)	26.7 ± 3.8 (18.5–33.9)	27.1 ± 2.7 (22.3–31.5)
Surgical side (right/left)		15/10	17/8	13/12
Years from surgery		3.1 ± 1.2 (1.0–4.9)	2.2 ± 1.0 (0.8–4.3)	2.9 ± 1.3 (1.0–5.0)
UCLA score	8.0 ± 1.9 (5.0–10.0)	7.3 ± 1.5 (6.0–10.0)	8.0 ± 1.4 (6.0–10.0)	8.3 ± 1.5 (6.0–10.0)
Harris hip score		98.2 ± 2.7 (91.3–100.1)	97.6 ± 2.9 (90.2–100.1)	98.7 ± 2.2 (92.4–100.1)

Values are mean ± SD with ranges in parentheses.

Fig. 1A–B This figure shows (A) the Proprio 5000 model and (B) a close-up of the moving platform. Figure 1A reprinted with permission from Perry Dynamics, Inc.

Fig. 2A–C Proprioception testing in double limb (A), single limb with pelvis neutral and balance maintained (B), and single limb with loss of balance, tilting of pelvis, and tilting and forward lean of trunk (C).

attached software generates a cumulative dynamic motion analysis score that ranges from 0 to 1440 with lower scores reflecting improved proprioception. The score is calculated from the following formula:

$$\sum_{k=1}^n \sqrt{(x_k - x_{(k-1)})^2 + (y_k - y_{(k-1)})^2 + (z_k - z_{(k-1)})^2}$$
, which incorporates data from deviations from the center of mass in six different planes. The average score for double-limb testing and each single-limb testing series was calculated. Kruskal-Wallis tests were used to compare mean scores among the four groups (total hip resurfacing arthroplasty, THA with femoral head > 32 mm, THA with femoral head ≤ 32 mm, and control subjects). Post hoc analyses were conducted to evaluate differences among groups controlling for Type 1 error across tests using the Bonferroni approach with p values < 0.05 considered statistically significant. The operative limb was normalized against the nonoperative limb and a percentage was calculated using the following formula: nonoperative limb

mean score/operative limb mean score * 100. For single-limb score in the control group, comparisons were made between right and left limbs and dominant versus non-dominant limbs. Because there was no difference in either comparison (Table 2), all 50 limbs were combined as a single control group to compare with the operative and nonoperative sides of the different cohorts of arthroplasty types. All statistical analyses were performed using SPSS for Windows, Version 20 (SPSS, Inc, Chicago, IL, USA).

Results

Double-limb scores were not different among the four groups compared ($p = 0.471$) (Table 3).

In single-limb testing, there was no difference between the dominant and nondominant limb in the control group ($p = 0.591$). With single-limb testing of the operative limb

Table 2. Single-limb scores for each side by arthroplasty type*

Group	Operative side score	Nonoperative side score	p value	Percent of nonoperative side
Total hip resurfacing arthroplasty	1104.3 ± 171.3 (773.7–1416.7)	1119.8 ± 197.4 (784.7–1377.7)	0.43	102 ± 12
Large femoral head THA	1159.5 ± 162.5 (846.0–1432.7)	1127.7 ± 190.1 (767.3–1382.0)	0.24	98 ± 15
Standard femoral head THA	1183.7 ± 117.3 (905.7–1341.7)	1164.5 ± 142.7 (788.7–1376.7)	0.45	98 ± 9
	Right leg score	Left leg score	p value	
Control subjects	1000.1 ± 196.1 (753.7–1363.0)	963.6 ± 149.4 (755.0–1331.0)	0.15	
	Dominant leg score	Nondominant leg score	p value	
Control subjects	993.4 ± 193.7 (753.7–1363.0)	970.2 ± 153.7 (755.0–1331.0)	0.38	

* Lower score indicates less average deviation from center of mass and thus better proprioception; values are mean ± SD with ranges in parentheses.

Table 3. Double-limb operative side scores of operative groups compared with control subjects*

Group	Double-limb score	p value (versus control subjects)
Total hip resurfacing arthroplasty (n = 25)	801.3 ± 20.7 (774.3–856.3)	0.52
Large femoral head THA (n = 25)	826.3 ± 69.6 (770.0–1078.7)	0.25
Standard femoral head THA (n = 25)	802.7 ± 38.9 (772.3–958.3)	0.94
Control subjects (n = 25)	807.0 ± 44.7 (764.0–934.3)	—

* Lower score indicates less average deviation from center of mass and thus better proprioception; values are mean ± SD with ranges in parentheses.

only considered, the total hip resurfacing arthroplasty group performed better than patients undergoing standard THA ($p = 0.041$), and there was a trend for total hip resurfacing arthroplasty to perform better than the entire THA population ($p = 0.07$) but not better than large-head THA ($p = 0.318$). However, when the operative limb was normalized against the nonoperative limb, the differences among groups were no longer significant. There were no statistically significant differences between total hip resurfacing arthroplasty and either standard or large-head THA or between standard and large-head THA with all arthroplasty types achieving a single-limb score within 2% of the unoperated limb (Table 2).

Operative limb scores were worse in all three hip arthroplasty cohorts than they were in the control group (p values of 0.006, < 0.001 , and < 0.001 for the total hip resurfacing arthroplasty, small-head THA, and large-head

THA, respectively; Table 4). Interestingly, the unoperated contralateral hips in the study group showed just as large a decline in proprioception as did the operative side (Table 5), suggesting that decreased proprioception is associated with early asymptomatic arthritis of the hip in young adults.

Discussion

Excellent outcomes with total hip resurfacing arthroplasty and THA have been well documented in the literature [2, 7, 11, 13, 18]. Among the proposed benefits of total hip resurfacing arthroplasty over THA is the potential for improved proprioception [15]. Previous attempts at comparing proprioception have relied on crude measures or incomplete surrogates of proprioception [9, 17, 19]. There have also been suggestions that the perceived improvement in proprioception with total hip resurfacing arthroplasty is not the result of the procedure itself, but perhaps more to do with the larger femoral head [12]. With newer, more advanced technology, we asked whether a measurable difference in proprioception could be demonstrated between patients who had undergone total hip resurfacing arthroplasty, standard-diameter femoral head THA, and large-diameter femoral head THA. We hypothesized that patients who had undergone total hip resurfacing arthroplasty would have improved proprioception and this improvement would be greater versus patients with standard-diameter femoral heads than those with large-diameter femoral heads but found that this was not the case. We also found that patients in the study group exhibited worse proprioception not only in the operated hip, but to a similar degree in the unoperated hip. This

Table 4. Single-limb operative side scores of operative groups compared with control subjects*

Group	Operative side score	p value (versus control subjects)
Total hip resurfacing arthroplasty (n = 25)	1104.3 ± 171.3 (773.7–1416.7)	0.006
Large femoral head THA (n = 25)	1159.5 ± 162.5 (846.0–1432.7)	< 0.001
Standard femoral head THA (n = 25)	1183.7 ± 117.3 (905.7–1341.7)	< 0.001
Group	Control single-limb score	p value (versus control subjects)
Control subjects (n = 50)	981.8 ± 173.5 (753.7–1363.0)	—

* Lower score indicates less average deviation from center of mass and thus better proprioception; values are mean ± SD with ranges in parentheses.

Table 5. Single-limb nonoperative side scores of operative groups compared with control subjects*

Group	Nonoperative score	p value (versus control subjects)
Total hip resurfacing arthroplasty (n = 25)	1119.8 ± 197.4 (784.7–1377.7)	0.003
Large femoral head THA (n = 25)	1127.7 ± 190.1 (767.3–1382.0)	0.002
Standard femoral head THA (n = 25)	1164.5 ± 142.7 (788.7–1376.7)	< 0.001
Group	Control single-limb score	p value (versus control subjects)
Control subjects (n = 50)	981.8 ± 173.5 (753.7–1363.0)	—

* Lower score indicates less average deviation from center of mass and thus better proprioception; values are mean ± SD with ranges in parentheses.

suggests that a decline in proprioception may be associated with early asymptomatic arthritis of the hip. We cannot determine from these analyses whether this is a primary causative factor or whether it is secondary to the subclinical alteration in anatomy, which predisposes to the early development of hip arthritis.

This study has some limitations. This is the first reported study with the PROPRIO 5000 apparatus examining patients who had undergone hip arthroplasty. Although this device has been shown to be a reliable option in assessing proprioception in the nonarthroplasty population [1], additional studies to validate this application in hip arthroplasty would be beneficial. Second, although pretest power analyses were done, given the lack of other data, certain assumptions

needed to be made in conducting a power analysis. The potential for this study to be underpowered exists. Further studies will help identify a more narrow range when reporting on the quantification of proprioception. Lastly, there is the potential for selection bias as it relates to the procedure each patient underwent. Although attempts were made through our inclusion and exclusion criteria to only identify highly performing patients who had undergone total hip resurfacing arthroplasty and THA, there is concern that those who sought out or were indicated for total hip resurfacing arthroplasty were potentially more athletic and active. Although there is no support in the literature that a more active or athletic lifestyle correlates with improved proprioception, our use of normalizing single-limb testing to the nonoperative side should remove this bias. This, along with the fact that single-limb testing was randomized, reinforces our finding that total hip resurfacing arthroplasty is not proprioceptively superior.

Our data failed to demonstrate a significant difference in proprioception between any of the groups in double-limb stance or in single-limb stance when normalized to the nonoperative side. We believe the design and power of this study support this assertion and that the observations are generalizable. This is the only study, to our knowledge, that compares these procedures using a sensitive tool to measure proprioception. Few other studies have examined proprioception and total hip resurfacing arthroplasty. Nantel et al. [17] showed improved postural balance during quiet standing in total hip resurfacing arthroplasty compared with 28-mm femoral head THA. Mont et al. [16] showed improved gait speed in patients with total hip resurfacing arthroplasty versus 28-mm femoral head THA and suggested that gait studies show that total hip resurfacing arthroplasty provides a more normal gait than conventional THA [14]. The proposed benefits of total hip resurfacing arthroplasty include proximal femoral bone stock conservation and restoration of more normal hip mechanics [8]. This may in turn lead to improved function and performance. These proposed benefits were not supported by this study. Although a lower score was recorded for single-limb testing with total hip resurfacing arthroplasty versus THA, this apparent benefit disappeared when normalized to the nonoperative limb.

In this cohort of high-functioning patients after total hip resurfacing arthroplasty and THA with varying head sizes, the hypothesis of improved proprioception after total hip resurfacing arthroplasty versus THA or large-head THA versus standard THA is not supported. Both groups perform similarly to healthy control subjects in double-limb testing (Table 3). In single-limb testing, the operative side proprioception score was nearly identical to the nonoperative side, indicating that proprioceptive recovery after both THA and total hip resurfacing arthroplasty can be virtually complete within the measurement capabilities of

currently available technology. Finally, the finding of significantly inferior single-limb scores in the nonoperative hips of all of the study cohorts compared with normal control hips suggests that altered proprioception may be associated with the early development of arthritis of the hip and this is worthy of further study.

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