Functional Recovery
After Hip Resurfacing and Rehabilitation

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Context: Surface replacement of the hip is aimed especially at active patients, and it seems to achieve optimal functional results in a short time if associated with a tailored rehabilitation protocol. Objective: To assess the functional outcome in a group of active patients after hip resurfacing. Setting: Gait-analysis laboratory. Participants: 8 patients and a control group of 10 subjects. Interventions: Patients treated with Birmingham hip-resurfacing system and a tailored rehabilitation protocol Main Outcome Measures: Clinical assessment (Harris Hip Score [HHS]) and instrumented gait analysis including muscular electromyographic assessment. Participants were assessed preoperatively and at 3 and 9 mo follow-up after surgery. Results: HHS showed a significant increase from the baseline to 3- (P = .008) and 9-month (P = .014) follow-up; 5 patients returned to sport. Gait pattern in the presented case series of patients improved substantially 3 mo postoperatively, and minimal further changes were present 9 months postoperatively. Residual abnormalities of time–distance and hip-kinematics parameters were consistent with a slow gait. A complete restoration of the muscle-activation pattern during gait was achieved. Conclusion: Hip resurfacing associated with a rehabilitation protocol based on the characteristics of the implant provides excellent clinical and functional outcome, especially for very active patients.

Keywords: gait analysis, joint arthroplasty

Surface replacement of the hip is a very valid alternative to traditional joint arthroplasty, aimed especially at active patients who have good bone quality. In fact, preserving both the head and the femoral neck, since only the surface of the proximal femur and the acetabulum have to be resurfaced, spares a large quantity of spongy bone, thus safeguarding its entire architecture.1 The characteristics of covering the prosthesis with a metal–metal coupling to favor the longevity of the prosthetic implant2–4 support its use in young patients. A more faithful reproduction of the natural anatomy of the coxofemoral joint submits the proximal bone to more physiological forces and obviates the problem of limb-length discrepancy.2,5–7 Moreover, the use of a large femoral head reduces dislocation rates and allows a more physiological range of motion.8 Being a conservative operation, due to its minimal invasiveness and in respect of the bone components of the head of the femoral neck, hip resurfacing finally allows good proprioception and a correct sense of joint excursion and positioning in the space of the treated limb, thus offering the possibility to plan a rehabilitation protocol that favors optimal functional results in a short time. Generally, the rehabilitation protocol proposed for these patients is the same as that used for conventional total-hip-replacement surgery, even if the patients submitted to joint resurfacing arthroplasty are often young, with high functional demands, often practicing sports, with high expectations, and potentially more adherent to rehabilitation programs. Until now, treatment tailored to the characteristics of the surgical technique and specific demands of these patients has not been defined.8

The rehabilitation protocol designed at our institute involves a specific program that leads patients to maximum functional resumption in a short time after the operation and possibly to the resumption of sports activity.9,10

The purpose of this study was to assess clinical and functional outcomes in a group of patients after hip resurfacing and undergoing a tailored protocol of rehabilitation treatment.

Methods

Participants

Eight patients (5 men and 3 women) with a mean age of 48.7 years (range 35–65), height of 173 cm (range 160–183), and weight of 78.5 kg (range 59–90), consecutively treated, were recruited and tested for clinical-functional outcomes. Inclusion criteria were primary osteoarthritis of the hip, body-mass index <30, age <65 years, and no other diseases. These participants before intervention

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engaged in physical activities of moderate and vigorous levels\(^\text{11}\) (Table 1).

In this series, only patients who completed the preoperative measures and 3- and 9-month follow-ups after surgical treatment and completed the planned rehabilitation program without any complication were included among a wide sample of patients. Our institute's scientific committee approved the study. Informed consent for participation in the study was obtained from all patients, and the rights of the subjects were protected.

Gait-analysis data were compared with the laboratory reference control group of 10 healthy subjects, mean age 59 years (range 42–72), 6 men and 4 women.

### Functional Evaluation and Gait Analysis

The Harris Hip Score\(^\text{12}\) (HSS) including severity of pain, functional activity, the presence or not of deformity, and joint range of motion was used for the functional evaluation. The HHS is one of the most widely used functional score systems in patients with hip replacement because of its high validity and reliability.\(^\text{13}\) Surgical treatment was performed on all the patients by the same team, and a BHR joint arthroplasty (Birmingham hip-resurfacing system) was implanted by posterolateral approach.

The instrumentation used for gait analysis included the optoelectronic Elite system (BTS, Milan, Italy) with 6 cameras. Data were acquired at a sampling rate of 100 Hz and filtered. The acquisition protocol used was the calibrated anatomical system technique.\(^\text{14}\) Surface dynamic EMG of the homolateral (operated side) erector spinae, contralateral erector spinae, gluteus medius, rectus femoris, lateral hamstrings, gastrocnemius, and tibialis anterior was detected simultaneously with kinematics data by means of a Telemg (BTS). The sampling rate was 500 Hz, and lower and upper cutoff frequencies of the amplifier were 40 and 200 Hz, respectively. Probes were positioned according to the guidelines suggested by Delagi et al.\(^\text{15}\) EMG signals were automatically processed off-line by a double-threshold statistical detector that gives, in a user-independent way, the muscle-activation intervals normalized to stride duration as system output\(^\text{16}\) in accordance with a previously described procedure.\(^\text{17}\)

### Data Analysis

Variables considered for statistics were HHS and gait-analysis data. Stance-phase duration and stride length on the operated side, cycle duration, cadence, and velocity of progression were considered among time–distance parameters. According to the methods of Benedetti et al.\(^\text{18}\) a parametric analysis was performed on hip kinematics and kinetics curves; the following parameters were extrapolated based on the gait-cycle subdivision introduced by Perry\(^\text{19}\); maximum anterior pelvic tilt, maximum pelvic rise during initial stance, maximum pelvic drop during swing, maximum pelvic posterior rotation, hip flexion at initial contact, maximum hip extension during gait cycle, hip extension at toe-off, maximum hip flexion during swing phase, hip active range of motion (ROM) in the sagittal plane, hip ROM in the coronal plane, maximum hip adduction during stance, maximum hip abduction during swing, hip ROM in the transverse plane, maximum hip internal rotation during stance, and maximum hip external rotation during swing phase. All parameters were expressed as mean and SD. Due to the small number of subjects included in this study, the statistical analysis was performed using the Montecarlo method for small samples. The nonparametric analysis was preferred because of the nonnormality of data. The Mann–Whitney test was used to compare patients at each follow-up with the control group. The Wilcoxon test was used for paired analysis (preoperative vs postoperative parameter comparison). Significant differences relative to the HHS were reported, including the effect size. The minimal detectable change of the time–distance parameters using the 95% confidence interval for mean of the control group was used, so the minimal detectable change was expressed as \(1.96 \times \text{standard error}\). For all tests, \(P < .05\) was considered significant. Statistical analysis was carried out with the Statistical Package for the Social Sciences (SPSS) software version 15.0 (SPSS Inc, Chicago, IL).

### Rehabilitation Protocol

All the patients underwent the following rehabilitation program. The phase of resumption of light sport activities was allowed only to patients who had asked to return to sport and in the absence of specific problems.

#### Preoperative Phase

In the session before surgery, general information about the postoperative course of rehabilitation and the main precautions was supplied. During the preoperative phase, each patient was instructed in the proper use of ambulatory devices (walking frame and then forearm crutches).
on level surfaces by a physiotherapist and during stair climbing. A simulation of activities to be undertaken in the immediate postoperative period was provided with respect to the correct postural alignment of the treated limb (light abduction, neutral and unloaded rotation) together with instructions on functional exercises of the healthy lower limb and the upper limbs, on the type of isometric contractions (gluteal, quadriceps) to be performed with the treated limb, on correct movement on the bed and bed-to-chair transfer, early load bearing on the operated limb, respiratory exercises, and flexion and extension activation of the ankles to prevent pulmonary and vascular complications.

**Postoperative Phase**

During hospitalization, all patients followed the same postoperative protocol up to discharge, generally 5 days after surgery. On the first day, continuous passive motion of the hip in the supine position was performed up to 45° of flexion. Sitting position was reached. On the second day, hip flexion was obtained up to 90° and the patients started walking with a walking frame. On the third day, walking was allowed with forearm crutches. The fourth day, patients were trained to climb stairs. Due to the posterolateral surgical approach, the patients were advised to limit the internal rotation of the hip for 3 weeks postoperatively.

According to the surgeon’s indications, use of 1 forearm crutch was discontinued on the operated side, and patients gained full weight bearing 1 month after surgery without aids.

**Moderate-Protection Phase After Discharge**

A progressive program including a whole range of rehabilitation care to optimize functional performance was prescribed at discharge. Specific items aimed at increasing hip ROM, muscle tone, mass, and strength were included. The following specific exercises were recommended: selective reinforcement of the gluteus maximus and medius and tensor of the fascia lata in side-lying, prone, and standing position; exercises to counteract the stiffness of hip anterior soft tissues, increasing the length of the hip flexors and the extensibility of the capsule by stretching postures and massage of the scar in side-lying position; exercises to favor the stabilization of the pelvis and correct alignment of the trunk in standing position; exercises enhancing proprioception to facilitate the loading acceptance during stance for correct walking-pattern recovery; neurocoordination and balance stimulation associated with strengthening exercises in closed and open kinetic chain with the use of small weights and elastic ankle bands in progressive degrees of resistance; and progressive stair ascent and descent with full load recovery.

In the final phase of recovery, the patients having achieved all the normal activities of daily life, the rehabilitation program involves a resumption of light sport activity (cycling, swimming) 2 months after surgery, medium-impact sport activities after 4 months, and even the practice of high-impact sport (running, jumping) after 6 months. Resumption of sport activity is always preceded by aerobic training and full recovery of both muscle strength and muscle endurance.

**Results**

**Functional Evaluation**

The mean HHS functional score before the operation was 62.25 (SD 15.8, range 35–89), at 3-month follow-up it was 95.2 (SD 3.2, range 90–98; \( P = .008 \) and effect size = 0.35), and at 9 months it was 95.1 (SD 7.9, range 81–100; \( P = .014 \) and effect size = 0.54; Table 2). The analysis of separate items shows that at 3-month follow-up there was a significant reduction in pain, while at 9-month follow-up 2 patients complained of intermittent pain during unusual activity. A significant improvement in overall function including cessation of limping, better execution of daily life activities, and ability to walk for limitless distances was reported. Five patients at the 9-month follow-up reported having returned to sport: 1 returned to swimming, 3 returned to riding bikes (one of them also returned to running), and 1 returned to golfing and skiing. According to the HHS score, no deformity was present in any of the patients before replacement and ROM was reduced preoperatively and recovered at 3-month follow-up.

**Gait Analysis**

**Spatiotemporal Gait Parameters.** Compared with the control group, patients from the current study preoperatively showed reduced stride length (\( P < .0005 \)), cadence (\( P < .0005 \)), and walking speed (\( P < .0005 \)) and a slightly increased gait-cycle duration (\( P < .0005 \)). Three months after the operation stride length and cadence had slightly increased with a consequent increase in walking speed. By the 9-month follow-up these results further improved but without achieving the values of the controls (Table 3). The minimal detectable changes for spatiotemporal gait parameters are expressed in Table 3.

**Gait Kinematics.** Preoperatively, the pelvis showed movement abnormalities in the coronal plane characterized by an increased rising of the affected side during the stance phase (\( P < .0005 \); Table 4). The hip showed reduced parameters in the sagittal plane: flexion at initial contact (\( H_1; P \leq .0005 \)), maximum extension in the stance phase (\( H_3; P \leq .0005 \)), extension at toe-off (\( H_4; P \leq .0005 \)), maximum flexion in the swing phase (\( H_5; P \leq .0005 \)), and ROM in the sagittal plane (\( H_6; P \leq .0005 \)). In the coronal plane, reduced hip adduction was seen in the stance phase (\( H_8; P = .014 \)) that limited the range of total movement in this plane (\( H_9; P = .001 \)) before the operation. In the transverse plane the range of total movement (\( H_{10} \)) was reduced preoperatively (\( P = .001 \))
### Table 2  Harris Hip Score

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative 3 mo</th>
<th>Wilcoxon test (pre–post 3 mo)</th>
<th>Postoperative 9 mo</th>
<th>Wilcoxon test (pre–post 9 mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score (maximum 100)</td>
<td>62.25 ± 15.8</td>
<td>95.2 ± 03.2</td>
<td><em>P</em> = .008</td>
<td>95.1 ± 7.9</td>
<td><em>P</em> = .014</td>
</tr>
<tr>
<td>Pain (maximum 44)</td>
<td>20 ± 12</td>
<td>43 ± 1.9</td>
<td><em>P</em> = .016</td>
<td>4.5 ± 6.5</td>
<td><em>P</em> = .030</td>
</tr>
<tr>
<td>Function (limp, support, distance walked, sitting, public transportation, stairs, put on shoes and socks; maximum 47)</td>
<td>33.6 ± 4.3</td>
<td>43.3 ± 02.4</td>
<td><em>P</em> = .007</td>
<td>45.6 ± 1.8</td>
<td><em>P</em> = .007</td>
</tr>
<tr>
<td>Range of motion (maximum 5)</td>
<td>4.6 ± 0.5</td>
<td>4.9 ± 0.4</td>
<td>ns</td>
<td>5 ± 0</td>
<td>ns</td>
</tr>
<tr>
<td>Deformity (maximum 4)</td>
<td>4</td>
<td>4</td>
<td>ns</td>
<td>4</td>
<td>ns</td>
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</tbody>
</table>

### Table 3  Level Walking: Time–Distance Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Preoperative</th>
<th>Mann–Whitney</th>
<th>Postoperative 3 mo</th>
<th>Mann–Whitney</th>
<th>Postoperative 9 mo</th>
<th>Mann–Whitney</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stance (%)</td>
<td>60.6 ± 2.1 (MDC 0.5)</td>
<td>62 ± 2.5</td>
<td>ns</td>
<td>61.7 ± 2.2</td>
<td>ns</td>
<td>61.1 ± 3.2</td>
</tr>
<tr>
<td>Cycle duration (s)</td>
<td>1.1 ± 0.1 (MDC 0.03)</td>
<td>1.3 ± 0.2</td>
<td><em>P</em> &lt; .0005</td>
<td>1.2 ± .1</td>
<td><em>P</em> = .001</td>
<td>1.2 ± .1</td>
</tr>
<tr>
<td>Cadence (strides/min)</td>
<td>53.4 ± 4.8 (MDC 1.2)</td>
<td>46.9 ± 6.3</td>
<td><em>P</em> &lt; .0005</td>
<td>48.8 ± 5.4</td>
<td><em>P</em> = .002</td>
<td>47.5 ± 4.8</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>132.6 ± 10.6 (MDC 2.7)</td>
<td>120.5 ± 22.3</td>
<td><em>P</em> &lt; .0005</td>
<td>128.7 ± 17.4</td>
<td><em>P</em> &lt; .0005</td>
<td>124.7 ± 14.7</td>
</tr>
<tr>
<td>Velocity (cm/s)</td>
<td>117.9 ± 13.7 (MDC 3.5)</td>
<td>94.7 ± 25.5</td>
<td><em>P</em> &lt; .0005</td>
<td>99.2 ± 18.8</td>
<td><em>P</em> &lt; .0005</td>
<td>104.4 ± 17.7</td>
</tr>
</tbody>
</table>

Abbreviations: MDC, minimal detectable change.

### Table 4  Level Walking: Kinematics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Preoperative</th>
<th>Mann–Whitney</th>
<th>Postoperative 3 mo</th>
<th>Mann–Whitney</th>
<th>Postoperative 9 mo</th>
<th>Mann–Whitney</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (max pelvic ant tilt)</td>
<td>–3.7 ± 4.4</td>
<td>–6.0 ± 5.0</td>
<td>ns</td>
<td>–5.7 ± 4.4</td>
<td>ns</td>
<td>–3.9 ± 2.3</td>
<td>ns</td>
</tr>
<tr>
<td>P2 (max pelvic rise stance)</td>
<td>1.7 ± 2.0</td>
<td>3.3 ± 2.8</td>
<td><em>P</em> = .03</td>
<td>2.8 ± 2.1</td>
<td>ns</td>
<td>2.0 ± 3.2</td>
<td>ns</td>
</tr>
<tr>
<td>P3 (max pelvic drop swing)</td>
<td>–2.1 ± 2.4</td>
<td>–3.2 ± 3.1</td>
<td>ns</td>
<td>–1.0 ± 1.7</td>
<td>ns</td>
<td>–0.8 ± 2.2</td>
<td>ns</td>
</tr>
<tr>
<td>P4 (max pelvic post rotation)</td>
<td>4.9 ± 5.9</td>
<td>4.6 ± 3.0</td>
<td>ns</td>
<td>4.5 ± 3.4</td>
<td>ns</td>
<td>4.9 ± 3.2</td>
<td>ns</td>
</tr>
<tr>
<td>H1 (flexion initial contact)</td>
<td>26.5 ± 6.3</td>
<td>20.5 ± 6.1</td>
<td><em>P</em> &lt; .0005</td>
<td>20.0 ± 2.6</td>
<td><em>P</em> &lt; .0005</td>
<td>2.2 ± 3.3</td>
<td><em>P</em> &lt; .0005</td>
</tr>
<tr>
<td>H3 (max extension stance)</td>
<td>–9.3 ± 6.2</td>
<td>–0.2 ± 4.1</td>
<td><em>P</em> &lt; .0005</td>
<td>–3.6 ± 4.8</td>
<td><em>P</em> &lt; .0005</td>
<td>–5.0 ± 4.2</td>
<td><em>P</em> = .003</td>
</tr>
<tr>
<td>H4 (extension at toe-off)</td>
<td>–3.3 ± 7.4</td>
<td>4.9 ± 4.9</td>
<td><em>P</em> &lt; .0005</td>
<td>2.4 ± 3.3</td>
<td><em>P</em> &lt; .0005</td>
<td>1.7 ± 3.5</td>
<td><em>P</em> = .003</td>
</tr>
<tr>
<td>H5 (max flexion swing phase)</td>
<td>30.0 ± 5.2</td>
<td>21.9 ± 2.8</td>
<td><em>P</em> &lt; .0005</td>
<td>24.4 ± 6.7</td>
<td><em>P</em> = .001</td>
<td>23.4 ± 2.9</td>
<td><em>P</em> &lt; .0005</td>
</tr>
<tr>
<td>H6 (ROM sagittal plane)</td>
<td>39.3 ± 4.4</td>
<td>24.4 ± 5.7</td>
<td><em>P</em> &lt; .0005</td>
<td>26.1 ± 3.5</td>
<td><em>P</em> &lt; .0005</td>
<td>28.5 ± 3.7</td>
<td><em>P</em> &lt; .0005</td>
</tr>
<tr>
<td>H7 (ROM coronal plane)</td>
<td>10.8 ± 2.7</td>
<td>5.2 ± 7.0</td>
<td><em>P</em> = .001</td>
<td>1.6 ± 2.2</td>
<td>ns</td>
<td>9.9 ± 3.2</td>
<td>ns</td>
</tr>
<tr>
<td>H8 (max adduction stance)</td>
<td>–4.8 ± 2.8</td>
<td>–1.2 ± 7.4</td>
<td><em>P</em> = .014</td>
<td>–5.0 ± 2.7</td>
<td>ns</td>
<td>–3.7 ± 3.3</td>
<td>ns</td>
</tr>
<tr>
<td>H9 (max abduction swing)</td>
<td>5.8 ± 3.0</td>
<td>5.8 ± 5.5</td>
<td>ns</td>
<td>5.3 ± 3.4</td>
<td>ns</td>
<td>6.1 ± 3.6</td>
<td>ns</td>
</tr>
<tr>
<td>H10 (ROM transverse plane)</td>
<td>14.3 ± 4.5</td>
<td>6.5 ± 9.1</td>
<td><em>P</em> = .001</td>
<td>12.9 ± 3.5</td>
<td>ns</td>
<td>12.5 ± 3.5</td>
<td>ns</td>
</tr>
<tr>
<td>H11 (max int rotation stance)</td>
<td>4.2 ± 5.6</td>
<td>0.8 ± 4.0</td>
<td><em>P</em> = .005</td>
<td>5.7 ± 4.3</td>
<td>ns</td>
<td>4.1 ± 4.2</td>
<td>ns</td>
</tr>
<tr>
<td>H12 (max ext rotation swing)</td>
<td>–8.1 ± 7.1</td>
<td>–2.8 ± 7.8</td>
<td><em>P</em> &lt; .0005</td>
<td>–4.3 ± 4.9</td>
<td><em>P</em> = .01</td>
<td>–3.9 ± 5.0</td>
<td><em>P</em> = .01</td>
</tr>
</tbody>
</table>

Abbreviations: max, maximum; ant, anterior; ROM, range of motion; int, internal; ext, external.
due to the reduction of both internal (H11; \( P = .005 \)) and external rotation (H12; \( P < .0005 \)).

At follow-ups at 3 and 9 months, movements of the pelvis and the hip in the coronal plane were normalized. By the 3-month and 9-month follow-ups, the hip maintained a reduction of parameters in the sagittal plane: flexion at initial contact (H1; \( P < .0005 \) at 3 months and \( P < .0005 \) at 9 months), maximum extension in the stance phase (H3; \( P < .0005 \) and \( P = .003 \)), extension at toe-off (H4; \( P < .0005 \) and \( P = .003 \)), maximum flexion in the swing phase (H5; \( P = .001 \) and \( P < .0005 \)), and ROM in the sagittal plane (H6; \( P < .0005 \) and \( P < .0005 \)). Finally, hip external rotation (H12) remained below control values even postoperatively (\( P = .01 \) and \( P = .01 \)).

**Electromyographic Activation**

Muscle-activation intervals recorded by surface electromyography showed a rather stable pattern in time with regard to the spinal muscles that were active in about 50% of patients during midstance with respect to only 10% of controls (Figure 1). The gluteus medius was active in stance phase in about 60% of patients preoperatively. At 9-month follow-up, all the patients had resumed a normal pattern. The rectus femoris and lateral hamstrings were regularly active in about 50% and 70%, respectively, of patients at early stance preoperatively. They had completely normalized at the 3-month follow-up for rectus femoris, while the hamstrings continued to be activated in about 40% of patients during late stance. Finally, the gastrocnemius and the tibialis anterior, which had presented cocontraction during midstance and terminal stance preoperatively, were normal at the 9-month follow-up.

**Discussion**

Several studies have used gait analysis as an evaluation tool in patients with conventional hip-joint arthroplasty,\(^{20-24}\) but there are relatively few in which the functional evaluation involved patients with resurfacing prostheses.\(^{25-29}\) A recent review\(^{29}\) suggested that hip resurfacing might result in a more normal gait than total hip replacement, even as it stated that further detailed gait-analysis studies are necessary. In a study performed in patients 1 year after hip resurfacing, Mont et al\(^{4}\) showed that gait kinematics and kinetics were more similar to those of controls than to those of patients with traditional hip arthroplasty. Since that study mainly analyzed joint moments at the hip during gait, comparison with the results of the current study is not possible. The only comparable result was gait speed (125.9 ± 18.2 cm/s), which was slightly higher than that reported here (104.4 ± 17.7 cm/s) at 9-month follow-up.

In the current case series, the clinical functional evaluation showed a net improvement in the clinical functional status of the hip after the operation. Pain was no longer present 3 months after hip resurfacing, while at 9-month follow-up 2 patients complained of occasional pain during unusual activity, without consequent functional limitations but reasonably correlated to the performance of more demanding motor activities.

Limping also disappeared and ability to perform activities of daily living improved, such as walking unlimited distances, ascending and descending stairs, putting on shoes and socks, and using public transport.

Gait analysis in the current case series showed improvement of hip kinematics and time–distance parameters. The minor alterations still present 9 months after the operation are mostly attributable to the reduced walking speed. Complete normalization of pelvic kinematics at 3 months, consistent with the full functional range of hip movement in the coronal plane, confirms the optimal functional resumption of the hip muscles without the need to use mechanisms to avoid pain triggered by joint load. This result is also confirmed by the electromyographic finding, unique in this series of patients with hip resurfacing, that showed full normalization of the activation pattern of the gluteus medius at 9 months. In the sagittal plane, a slight lowering of hip motion persisted due to the reduced flexion at heel strike and extension in the terminal stance phase and toe-off, although the thigh muscles, rectus femoris, and hamstrings showed a resumed normal activity pattern already at 3 months. This finding is also in agreement with the results so far reported for traditional hip prostheses.\(^{5,20-24}\) Although the patients followed suitable rehabilitation treatment and did not present any restriction of hip ROM at the clinical examination (as reported by means of the HSS), it is evident that the reduced active ROM during gait requires further assessment to establish its actual relationships with velocity of progression.

Current studies on the outcome of resurfacing arthroplasty are more focused on evaluating wear and the risk of fracture and loosening than the effective functional result on the patients’ motor activities. A recent study on the outcome after resurfacing arthroplasty,\(^{5} \) however, despite the subjects having shown general high levels of function, physical activity, and satisfaction after resurfacing, revealed that a certain number of patients still complain of some difficulties 1 year after the operation. Limitations in gait persist in 25% of patients, the same percentage of patients does not regain full muscle strength, and their ROM is limited. Those authors conclude that these suboptimal results might be due to the prescription of the conventional rehabilitation protocol for traditional arthroplasty to patients with resurfacing prostheses, whereas the results could be improved with a rehabilitation program tailored to the specific needs of patients with resurfacing arthroplasty. Although these patients can perform higher-level activity\(^{30}\) without negative consequences, it is necessary to establish a suitable temporal sequence to avoid joint overloads. Therefore, the period of rehabilitation, which is performed outside the hospital and aimed at the resumption of more demanding functional activities, is very important.\(^{31}\) The results of this study allow us to define in further detail some aspects of the rehabilitation protocol that must place more attention on reduced functional articular excursion, to avoid the risk of...
Figure 1 — On–off muscle timing of all operated patients as percentage of gait cycle (x-axis). The pattern of muscle activity at the operated leg is presented as percentage of number of patients (y-axis) for each muscle: HES, homolateral erector spinae; CES, contralateral erector spinae; GM, gluteus medius; RF, rectus femoris; LHAM, lateral hamstrings; GAS, gastrocnemius; TA, tibialis anterior. Preoperative and follow-up data are superimposed on control data.

possible overloads at the hip or other joints, particularly in patients who returned to sport. One of the limits of this study, besides the small number of patients examined, is that we did not assess the other articular segments that can be recruited for possible compensation roles. Moreover, it may be that the regimen of limb loading adopted in this series may be too cautious. Patients used forearm crutches until the second week after surgery and 1 crutch until the fourth week. Since there is evidence today that an early full loading in noncemented prostheses has no adverse
Conclusion

The aim of the current study was to assess functional outcomes in a group of patients with hip resurfacing and undergoing a tailored rehabilitation protocol.

By the third postoperative month, the patients had a net improvement in the functional score and instrumental parameters of gait, thus confirming the hypothesis of rapid functional restoration after resurfacing. Subsequently, a progressive consolidation of the positive results obtained was observed after 9 months. Residual slight gait abnormalities are presumed to be related to the slow gait speed. With correct indication and when supported by an adequate rehabilitation approach, hip-resurfacing arthroplasty offers good results in terms of early functional restoration due to its intrinsic characteristics of preserving proprioception, better ROM, and reduced risk of dislocation because of the large size of the femoral head. The study of hip functional performance during gait in terms of kinematics, kinetics, and muscle activity is, however, fundamental in these patients, who often need to return to a high level of physical performance and to sport. Further studies on larger samples of patients and during different daily living or sport activities are required to better understand the biomechanical performance of the resurfaced hip in time.

References


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