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Original article

Minimally invasive surgery supercapsular percutaneously-assisted total hip (SuperPath) arthroplasty: Applicability to mildly dysplastic osteoarthritis and early recovery of lower limb function

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Abstract. *Background and aim:* The benefits of minimally invasive surgical techniques in total hip arthroplasty (THA) are well known, but concerns about applying SuperPATH in patients with secondary OA of acetabular dysplasia do not have been reported. We aim to evaluate whether SuperPATH is applicable to secondary OA, furthermore, to quantify the recovery of lower extremity function. *Methods:* 30 patients with secondary OA admitted for THA applying SuperPATH were investigated. Clinical Japanese Orthopaedic Association (JOA) Score and radiographical evaluation were performed. Following was examined pre- and early postoperatively; pain level, blood tests, TUG and 10-M walking time for lower limb recovery. *Results:* Preoperative radiographic measurements revealed an average Sharp angle of 46.2 ± 2.8 degrees and CE angle of 19.4 ± 7.3 degrees. 29 THAs had Crowe Type I and 1 THA had Crowe Type II. JOA score improved from 48.8 preoperatively to 91.5 at 2 months postoperatively. The perioperative pain assessment (VAS) averaged 7.0±1.5 preoperatively, 4.6±2.6 on the first postoperative day, then decreased gradually to 1.2±1.4 at 2 weeks. Blood data showed that creatine kinase, myoglobin, and CRP were significantly elevated on the day after surgery, but they normalized at 2 weeks postoperatively. Both TUG and 10M walking time showed slightly higher values at 1 week postoperatively compared to preoperatively but recovered to the same level as preoperatively at 2 weeks after surgery. *Conclusions:* Our data suggests that SuperPATH approach to THA for secondary OA of dysplasia was applicable to mildly dysplastic OA and achieved an early recovery of lower limb function. (www.actabiomedica.it)

Key words: total hip arthroplasty, SuperPath approach, early recovery, minimally invasive surgery, percutaneous assisted total hip

Introduction

In recent years, various hip joint surgical approaches have been introduced to reduce dislocation, a complication after total hip arthroplasty (THA), and to improve early return to society and Activities of Daily Living (ADL), and their early recovery and low dislocation rates have been reported. SuperPath approach is a kind of posterior approach that does not involve releasing the external rotator muscles but only partially releasing and suturing the posterior capsule, thus preserving the muscles and tendons around the hip. SuperPath-THA is performed by entering hip joint between the posterior border of the gluteus medius and the external rotator muscles and inserting a device for acetabular manipulation using a portal through a separate skin incision. SuperCAP (Murphy 2004, 2013) (1, 2) is a similar method of hip joint

entry between the posterior border of the medius muscle and the piriformis, but the piriformis is allowed to be released and the flap of the capsule is formed anteriorly. The femoral head was resected after femoral manipulation without dislocation, and then a special angled device was needed for acetabular manipulation, which was complicated. On the other hand, PATH (Penenberg et al. 2008) (3), which was introduced as a new technique for acetabular manipulation including the portal through a separate incision with the same penetration method, is beginning to be performed at the same time. Both SuperCAP and PATH have been reported to have excellent short-term results (1-3). SuperPath approach is a technique that combines PATH with the creation of a separate skin incision portal to compensate for the complications of SuperCAP and differs from SuperCAP and PATH in that it preserves the piriformis and uses a single straight incision of the capsule. This technique was first reported by James Chow et al. in 2011 (4), and since then many reports have been published in Europe and the United States, showing that the short-term results are comparable to or better than those of other THA techniques (5-7). However, unlike in Europe and the United States, where primary osteoarthritis (OA) is more common, it is not clear whether similar results can be expected for secondary OA in Japan where acetabular dysplasia can be main cause of secondary OA.The purpose of this study is to evaluate whether the SuperPath approach is applicable to secondary OA. Furthermore, to quantify the recovery of lower extremity function in patients undergoing THA with the SuperPath approach.

Patients and methods

Of the patients scheduled for THA for secondary OA of dysplasia at our department between March 2016 and March 2018, 30 patients who agreed to participate in the study and underwent THA using the SuperPath approach were included. Patients with a preoperative Xp dislocation degree of Crowe Type (8) 3 or 4 or a preoperative UCLA Activity Score (9) of 2 or less were excluded.

This study was approved by our Institutional Review Board. 30 THAs included 5 males and 25 females with a mean age at surgery of 66 ± 8.7 years, mean BMI of 23 ± 2.2 (kg/m^2), and mean postoperative observation period of 25 months (15-38 months). The preoperative UCLA Activity Score was 3 (21 THAs), 4 (7 THAs), and 6 (2 THAs), respectively (Table 1).

All patients underwent THA under general anesthesia by using the SuperPath approach to the joint (1). All subjects used MicroPort Orthopedics's (Arlington, TN, USA) Dynasty Biofoam cementless cups on the acetabular side, and Profemur Z (29 THAs) and Profemur TL (1 THA) on the femoral side. Modular necks were used for all femoral stems. No screws were used for cup fixation, and no THAs required massive bone grafting on the acetabulum. Ceramic heads were used in all THAs, and the head size was determined by the diameter of the placed cup (28 mm in 6 THAs, 32 mm in 24 THAs). A navigation system (Stryker) was used in 22 THAs for intraoperative acetabular manipulation, and intraoperative XP control was performed in all THAs to confirm implant placement and alignment. For postoperative pain management, all patients had only Nsaids taken orally for two weeks.

Intraoperative evaluation items included operative time and intraoperative blood loss. JOA (Japanese Orthopaedic Association) scores (Pain;0-40, ROM;0-20, Walking ability;0-20, ADL;0-20, minimum 0 to maximum 100) (10) were clinically evaluated preoperatively, 2 months postoperatively, and 1 year postoperatively. Perioperative pain was evaluated preoperatively, 1 day postoperatively, 2 days postoperatively, 3 days postoperatively, 1 week, 2 weeks, 3 weeks postoperatively, and 2 months postoperatively using the Visual Analog Scale; VAS (minimum 0 to maximum 10). Complications (dislocation, fracture, infection, pulmonary embolism, neuropathy and so on) were also investigated up to 1 year postoperatively.

Table 1. Study patient demographic characteristics.

Number of Patients	30
Age (years)	66±8.7
Sex Ratio (M/F)	5/25
Height (cm)	154.9±7.6
Weight (kg)	56±8.4
BMI (kg/m^2)	23±2.2

To assess recovery of lower limb function, the Time Up and Go test (TUG) (11) and 10-meter (10M) (12) walk time were measured preoperatively and at 1, 2, and 3 weeks postoperatively. In addition, the number of postoperative days until the patients could a) walk more than 50-meter (50M) with a stick, b) ascend and descend stairs with a handrail, and c) put on and take off socks by themselves without any self-help devices were also evaluated.

Serum creatine kinase (CK, IU/L), myoglobin (MG, ng/mL), and C-reactive protein (CRP, mg/dL) were measured preoperatively, 1 day postoperatively, 1 week postoperatively, and 2 weeks postoperatively.

Radiographically, the degree of acetabular dysplasia was measured using the Sharp angle (13) and Center-Edge (CE) angle (14) from a simple preoperative hip x-ray, and the degree of dislocation was evaluated using the Crowe Type (8). Immediately postoperative and 2-month postoperative simple hip X-rays were compared to evaluate implant migration and fixation (15, 16). Implant alignment was also evaluated by hip CT at postoperative 2 months.

Results

The mean operative time was 118±11 minutes, and the intraoperative blood loss was 417±206 ml.

JOA score improved from 48.8 preoperatively to 91.5 at 2 months postoperatively and 95.1 at 1 year postoperatively (Table 2, Figure 1). The perioperative pain assessment (VAS) averaged 7.0±1.5 preoperatively, 4.6±2.6 on the first postoperative day, then decreased gradually to 2.4±2.0 at 1 week, 1.2±1.4 at 2 weeks, and 0.1±0.3 at 1 month postoperatively (Table 2, Figure 2).

The trends of blood test data showed that CK, MG, and CRP were significantly elevated on the day after surgery ($p<0.01$), but they almost returned to the preoperative level at 1 week postoperatively and normalized at 2 weeks postoperatively (Table 2, Fig. 3).

Both TUG and 10M walking time showed similar trends in functional recovery of the lower extremity, with slightly higher values at 1 week postoperatively compared to preoperatively but recovered to the same level as preoperatively at 2 weeks after surgery and were lower than that preoperatively at 3 weeks postoperatively (Table 2 Figure 4). The Median time from postoperative to 50M independence in walking with a cane was 3 days (min. 1 day, max. 14 days), to independence in stair climbing with handrails was 3 days (min. 2 days, max. 7 days), and to independence in putting on and taking off socks was 6 days (min. 2 days, max. 10 days).

As for complications, there were no dislocations, no infections, and no subjects of pulmonary embolism. However, 2 THAs had cracked fractures of the proximal femur at the time of intraoperative stem insertion, and wire fastening was conducted as an additional intraoperative procedure, and the clinical course was good thereafter. 2 THAs had sciatic nerve palsy immediately after surgery but recovered completely 3 months after surgery with conservative treatment.

Preoperative radiographic measurements revealed an average Sharp angle of 46.2 ± 2.8 degrees and CE angle of 19.4 ± 7.3 degrees for acetabular dysplasia, and regarding Crowe Type, 29 THAs had Crowe Type I and 1 THA had Crowe Type II. Postoperative radiographic evaluation revealed abduction angle of 40 ± 4.2°, anatomic anteversion angle of 24 ± 5.7° for a cup, and an anteversion angle of 34 ± 9.8° for the stem. Stem alignment was within 2 degrees of varus/valgus for all THAs, but anterior insertion (flexion insertion) of more than 5 degrees was identified in 2 THAs (8%) on lateral femoral images. Comparison of the immediate postoperative and 2-month postoperative x-rays showed no change in cup alignment in all THAs. Stem subsidence of more than 2 mm was observed in 2 THAs (8%), but there was no subsequent progression. No loosening of the cup or stem was observed at 2 months postoperatively in all THAs.

Discussion

This study was conducted to study the outcomes after the SuperPath technique for secondary OA of dysplastic patients, a condition that is common in Japan and results of which are yet to be reported. For this purpose, the study collected patients' outcomes using JOA, reduction of pain using VAS, functional

Table 2. Pre-OP and post-OP study subject clinical outcomes.

Pre-OP				Post-OP															
Mean SD				1day		2day		3day		1week		2weeks		3weeks		2months		1year	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Blood Test	CK (IU/L)	76.6	28.5	553.8	222.1					119.7	50.8	48.4	25.2						
	MG (ng/mL)	33.7	12.3	322.3	135.3					38.3	10.6	32.8	10.7						
	CRP (mg/dL)	0.2	0.3	2.7	1.3					1.8	1.2	0.6	0.7						
JOA score	pain	13.3	4.7													38.8	2.1	40.0	0.0
	ROM	12.9	4.3													18.5	1.3	19.2	0.8
	Gait	9.6	2.3													16.7	2.7	17.4	3.5
	ADL	13.0	2.1													17.3	2.7	18.5	2.3
	Total	48.8	8.3													91.5	7.2	95.1	6.1
TUG (sec.)		9.6	3.1							10.7	2.5	9.7	3.1	8.9	2.9				
10MGait (sec.)		9.4	2.5					14.2	3.2	11.8	4.5	9.6	2.5	9.0	2.0				
VAS(0-10)		7.0	1.5	4.6	2.6	4.0	2.0	3.7	2.1	2.4	2.0	1.2	1.4	0.8	1.4	0.1	0.3		

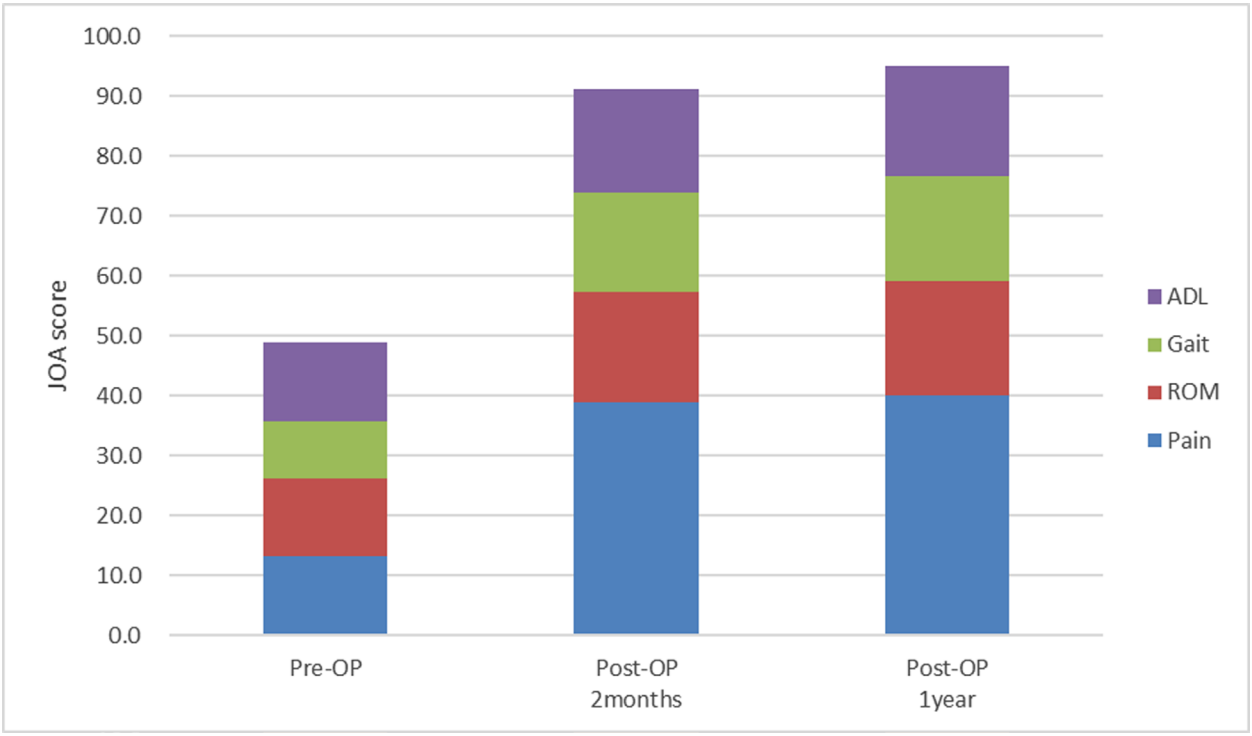

Figure 1. Pre-OP and post-OP study subject JOA Score.

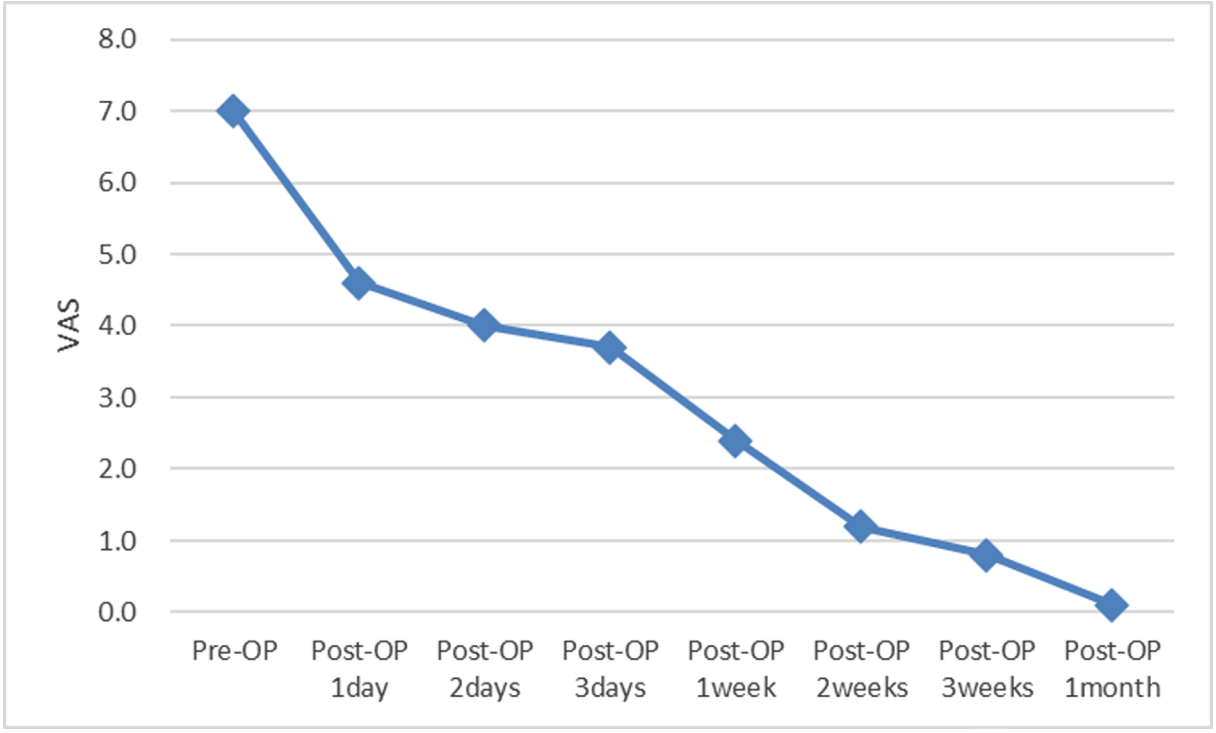

Figure 2. Pre-OP and post-OP study subject VAS.

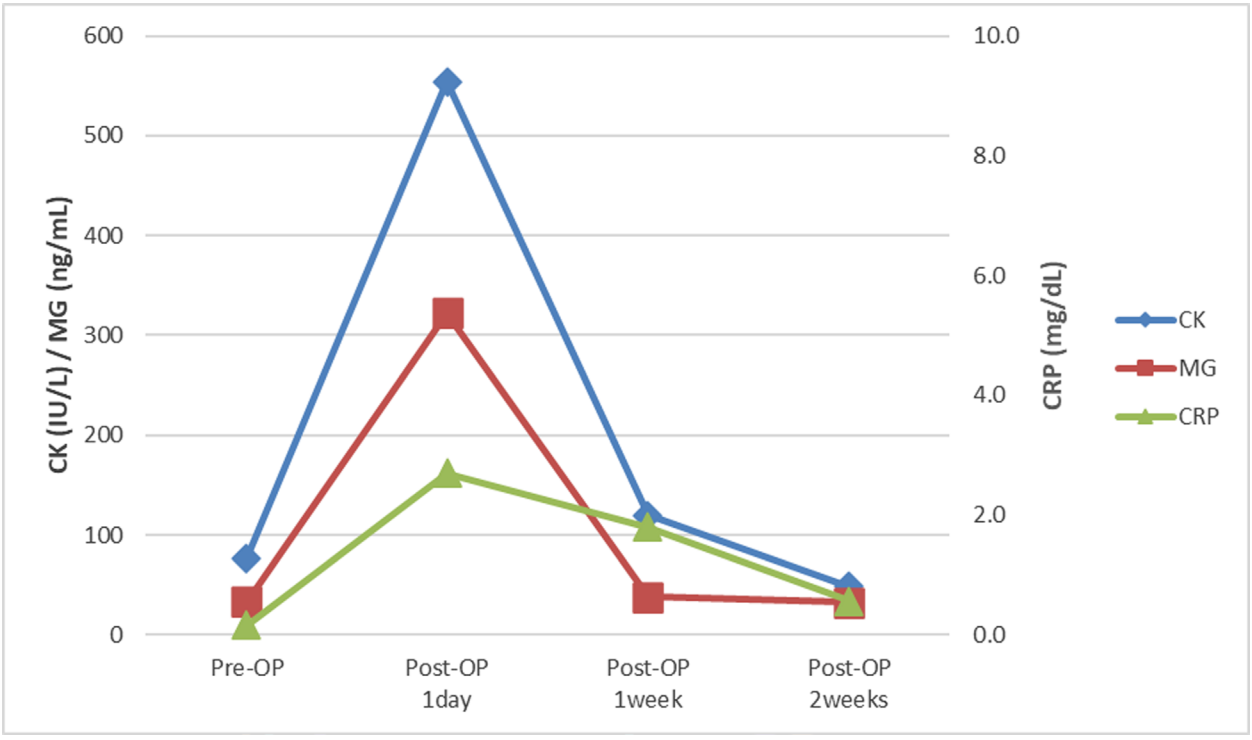

Figure 3. Pre-OP and post-OP study subject blood test data.

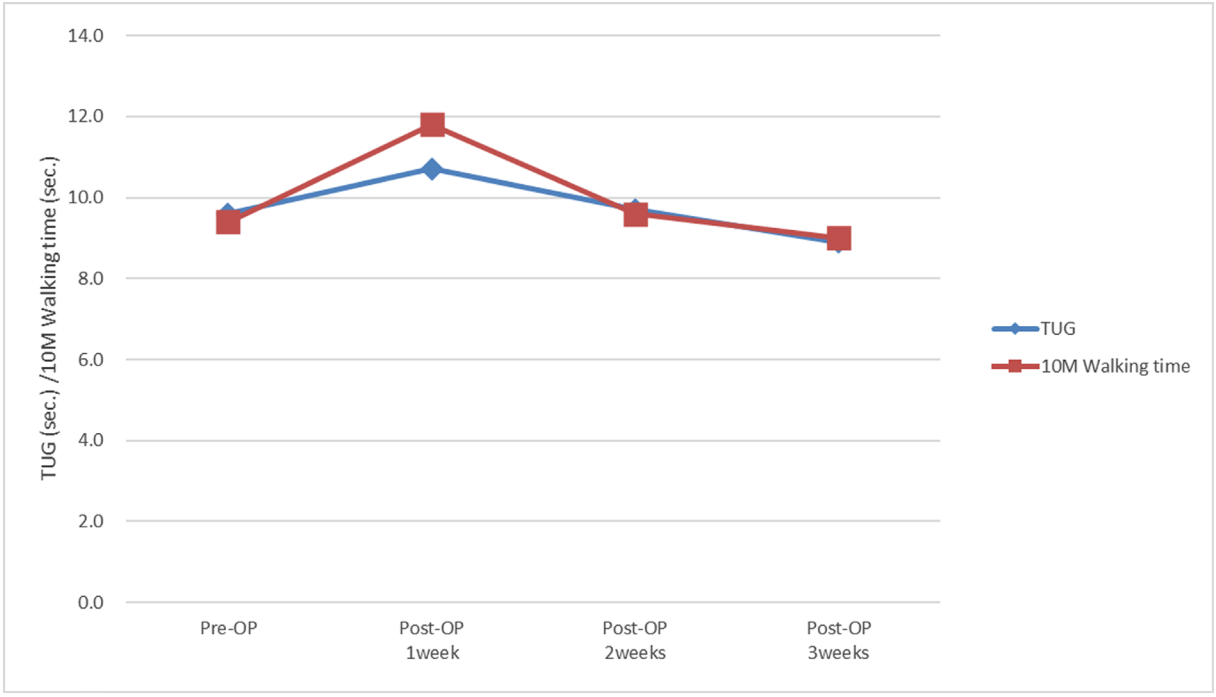

Figure 4. Pre-OP and post-OP study subject TUG and 10M walking time.

activities using TUG and custom walking tests and analysis biomarkers from blood tests.

The results of this study showed that the JOA score recovered from 48.8 preoperatively to 91.5 at 2 months postoperatively and 95.1 at 1 year postoperatively, indicating a good clinical outcome. The perioperative VAS was 4.6 ± 2.6 on the first postoperative day, 2.4 ± 2.0 at 1 week, 1.2 ± 1.4 at 2 weeks, and 0.1 ± 0.3 at 1 month after surgery. Branco et al (17) compared SuperPath and conventional THA and reported significantly lower VAS for the SuperPath approach on postoperative day 3 (VAS: 4.73) and at 1 month postoperatively. Ramadanov et al (6) performed a meta-analysis comparing SuperPath and conventional approaches to THA and found that the VAS was significantly lower for the SuperPath approach at 7 days postoperatively. The results of this study suggest that the pain in the early postoperative period was low, like the reports reported by another researchers.

The blood test data in this study showed that CK, MG, and CRP were significantly higher on the day after surgery than preoperatively ($p<0.01$) but returned to preoperative levels at 1 week postoperatively and normalized at 2 weeks postoperatively. Tottas et al (7) compared SuperPath and Hardinge THA and examined blood tests to assess soft tissue damage and reported significantly lower CRP levels immediately after surgery and on postoperative day 1 in SuperPath patients. Li et al (18) compared SuperPath with THA using the conventional posterior approach and found that SuperPath patients had significantly lower CRP and CK on postoperative day 3. Cohen et al (19) evaluated early postoperative blood tests to assess muscle damage in THA using three approaches (Modified Watson-Jones, MiniPosterior I, MiniPosterior II) and found that CK and MG peaked around 8 hours postoperatively but had not yet returned to preoperative levels on postoperative day 3. Although no other reports to the extent that we could confirm the date when blood parameters (CK, MG, CRP) returned to preoperative levels, they were shown to be significantly lower compared to the Conventional approach up to 3 days postoperatively, and other MIS approaches showed a peak at 8 hours postoperatively for CK and MG value. These study results seem to support the fact that blood test parameters in this study returned to almost preoperative status at 1 week postoperatively and normalized at 2 weeks postoperatively.

Looking at the recovery of lower extremity function in this study, both TUG and 10M walking time showed a similar trend, with slightly higher values at 1 week postoperatively compared to preoperatively but recovered to the same level preoperatively at 2 weeks and was less than preoperative value at 3 weeks postoperatively. Zhang et al (20) performed a postoperative gait analysis of two groups, SuperPath and THA with a Hardinge approach and found that walking speed was significantly faster in the SuperPath group on postoperative day 5 and 4weeks and was not significant at 12 weeks postoperatively. And SuperPath step length was significant larger at day5 postoperatively and was not significant at 12weeks postoperatively. Dou et al (21) divided THA patients with the SuperPath approach into two groups (early rehabilitation group and regular rehabilitation group) and compared the degree of recovery and reported that recovery of ADL and balance function was particularly good at 1 month postoperatively, with the early rehabilitation group showing significantly faster recovery. The results of this study showed that the median time from postoperative to 50M independent walking with a cane was an average of 3 days, to independent stair up/down with handrails was an average of 3 days, and to independent sock putting on and taking off was an average of 6 days. Fink et al (22) compared two groups of THA using the MIS posterior approach and the Standard posterior approach, and reported a significant difference in the MIS posterior approach group, with an average of 2.7 days to walk with a cane in the hospital ward and 5.3 days to stair up/down. Previous reports have shown significantly faster recovery of objective parameters in gait analysis after THA surgery with SuperPath approach compared to the conventional approach, and the results of this study also support the previous reports. The report by Dou et al (15) also suggests a significant influence of early postoperative rehabilitation intervention.

The patient's blood test data as an indicator of surgical invasion returned to the preoperative level at 1 week postoperatively, and the patient's subjective postoperative pain evaluation of the VAS showed a low value of 2.4 ± 2.0 at 1 week postoperatively, suggesting

that postoperative pain may be less compared to other conventional approaches, and as a result, may lead to early recovery of lower limb function.

Regarding complications, the results of this study showed no THAs of postoperative dislocation, infection, or serious pulmonary embolism, but two patients had intraoperative crack fractures of the proximal femur, and wire clamping was performed as an additional intraoperative procedure. James Chow et al (4) reported good clinical results in 110 THAs when SuperPath was first introduced, but complications occurred in 8% of THAs, including 3 femoral fractures, 2 acetabular fractures, 2 greater trochanter fractures, 1 loss of acetabular fixation, and 1 dislocation, most of which were intraoperative, and the authors cited poor bone stock and osteoporosis as risk factors. Lei et al (23) studied THA using the SuperPath approach for femoral neck fractures and osteonecrosis of the femoral head and found a learning curve of 40 THAs in terms of intraoperative blood loss and operative time. Both 2 intraoperative fracture THAs in this study were women over 80 years old, and it is assumed that poor bone stock was a factor, but the learning curve may also be a factor. The present study also included two THAs of sciatic neuropathy in the immediate postoperative period, but our extensive reading did not identify any other reports of postoperative neuropathy. In the present approach, the sciatic nerve is usually not directly viewed intraoperatively, but considering that most of the intraoperative manipulations are performed in hip flexion, the sciatic nerve is close to the surgical field, and the external rotator muscles are retracted backward with the Retractor. Thus, it is highly possible that sciatic nerve damage was caused by Retractor. Fortunately, complete recovery from the neuropathy was observed 3 months postoperatively with no therapeutic treatment intervention but only follow-up observation. When posterior soft tissue tension is tight, manipulations should be performed with hip towards a little extension, and the protective Retractor operation should be important.

Regarding implant alignment, the results of this study showed that the cup alignment was good with abduction angle of 40 ± 4.2° and anteversion angle of 24 ± 5.7°. For stem alignment, the anteversion angle was 34 ± 9.8°, and the stem was placed within 2 degrees of varus/valgus in all THAs. However, an anterior insertion (flexion insertion) of more than 5 degrees was observed in 2 THAs (8%) on lateral view of the femur. Although no specific clinical complications were observed in these 2 THAs, we believe that careful follow-up is needed in the future. Some comparative studies between SuperPath and various approaches (24, 25) have evaluated implant alignment, and no significant malalignment was found among the reports we read widely.

The study results of Crowe Type I and II showed that the implants were well positioned, and no implant loosening was observed in the short term, suggesting that the SuperPath approach could be applied for THA for secondary OA of dysplasia. However, for Crowe Type III and above, the degree of upward dislocation of the hip is more significant, making it difficult to preserve the external rotator muscles during surgery, and additional procedures such as release of the joint capsule are expected to be necessary. In this study, the mean Sharp angle was 46.2 ± 2.8 degrees, and the mean CE angle was 19.4 ± 7.3 degrees, and there were no THAs that required massive bone grafting to the acetabulum or additional screws for cup fixation. However, in THA of significant dysplasia, screws may be necessary for bone grafting and cup fixation. Regarding the recovery of lower limb function in patients who underwent THA using the SuperPath approach, in this study, both TUG and 10M walking time recovered to the same level as before surgery at 2 weeks postoperatively. The median time from postoperative to 50-meter cane walking independence was 3 days, to stair climbing independence using a handrail was 3 days, and to sock dressing independence was 6 days. The results showed that the patients achieved faster recovery compared to the conventional approach reported by other researchers.

Limitation

This study still has the following limitations. First of all, it is a small number of cases. Because it was our first SuperPath study, we started with a total of 30 cases. Other limitations are that it is not a comparative study and that only mildly deformed patients of Crowe Type I and II are included.

Conclusions

SuperPath approach to THA for secondary OA of dysplasia was applicable to mildly dysplastic OA of Crowe Type I and II and achieved an early recovery of lower limb function compared to the conventional approach described by various authors. However, future validation is needed for OA with severe deformity (Crowe Type III and IV).

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Conflicts of Interest: All authors declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Consent and Ethical Statement: This study was conducted in compliance with the Declaration of Helsinki. This study was approved by Osaka Minami Medical Center ethics committee(Study ID: 27-43, Approved Date: December 21, 2015). This study participants informed consent was obtained by written documents.

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