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# **Research Article**

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# Clinical observation of early rehabilitation of childhood femoral head necrosis in a low stress environment

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#### **ABSTRACT**

**Background:** Objective: To observe and study early rehabilitation processes in children with femoral head necrosis (Perthes disease) in a low stress environment.

**Methods:** Twenty-eight symptomatic patients underwent surgery. The effected coxa was supported with a coxa multi-functional external fixation, which created a low stress environment in the patient's hipbone. Complete data and documentation of follow-up were received in this research. The preoperative and postoperative changes in iconographical features were observed, thickness of epiphysis and degrees of hip flexion and extension were examined.

**Results:** Follow-up ranged from 2 to 7 years (mean 41 months), postoperative clinical complications were slight in all of the patients. Radiographic evaluation showed that the deformed groove caused by high pressure of the upper outside of femoral head was repaired under a low stress environment. High density necrosis shadows shrank rapidly within three months. The thickness of the epiphysis was obviously increased (P < 0.01), and the femoral head gradually became plump. Activities of the hip such as flexion and extension were significant improvement (P < 0.01). **Conclusions:** Under a low stress environment, femoral head necrosis in children was repaired. The groove, high density necrosis head and thickness of epiphysis were important features of femoral bone repair in children. The efficiency of repair was directly related to a low stress environment and the extent of the disease.

Keywords: Perthes disease, External fixation, Femoral head necrosis, Low stress environment

#### INTRODUCTION

Perthes disease is a juvenile idiopathic osteonecrosis, in which the bone dies provisionally and the blood supply of femoral head is not sufficient. The causes of the disease are still unclear and therapies are controversial. Urrently, it is believed that Perthes disease is a self-limited disease. However, even after being spontaneously cured, the femoral bone appears deformed, with poor containment and shrinkage or other sequelae. Serious osteoarthritis can appear in advanced stages and the hip

joint may eventually lose function.<sup>3</sup> Traditional therapies, including synovectomy, drilling decompression, vessel pedicle tissue implantation, all kinds of external supporting frames and pulling methods, cannot completely reduce the pressure and impact of the acetabulum on the enlarged femoral head. It is pelvic osteotomy and intertrochanteric varus osteotomy that can change the distribution of the acetabulum pressure on the femoral head or change the bearing site of the femoral head, which cannot be obtained through traditional therapies.<sup>5,6</sup> We have designed and made multi-functional

external fixator for children, it should be fixed at the acetabulum and proximal end of the femur ,which would maintain lower limb outreach and internal rotation and increase femoral head containment in the acetabulum, allowing partial flexion and extension activities of the coxa in the sagittal plane. This would create a low stress environment in the coxa of these patients. The special phenomenon and its characteristics were observed, which during early rehabilitation processes of the necrotic femoral head under a low stress environment.<sup>7</sup>

#### **METHODS**

We used self-designed multi-functional external fixator (Figure 1) to cure Perthes disease of children. All of the patients went directly for surgery by a same group of doctors after diagnosis.

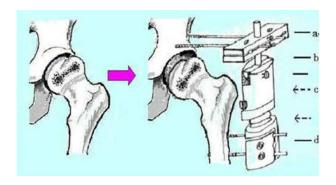


Figure 1: Diagram of effected coxa under a low stress environment The horizontal fixed screw clamp (a) and the height adjustment rod (b) were fixed by two screws. The height adjustment rod (b) and the pillar (c) were linked through interlocking hinge joints. The rod (c) and vertical screw clamp (d) were fixed through universal joints.

Patients were treated with basal or continuous epidural anesthesia. Patients were put in the supine position and their hips were elevated. The coxa anterolateral approach (Smith-Peterson incision) was introduced to cut a 12 cm long incision. Layered cutting was used to enter the space between the rectus femoris and tensor fasciate latae. The ascending ramus of the lateral femoral circumflex artery was ligated. The periosteal of the iliac bone was stripped. The articular capsule was exposed and opened to expose the coxa. Four screws were nailed at the upper rim of the acetabulum and the middle of the femoral shaft based on the hip frame design. The skin around the screw edge was stitched. The patient's limb was stretched out ~20-30° and rotated internally ~20-30° so that traction of the diseased limb was made after complete containment of the femoral head inside the acetabulum to create ~0.5-1.0 cm of space inside the joint cavity (Figure 1). Then, the external supporting frame was loaded to strengthen and fix the hip and femoral head. The layered cut was stitched after the screws were fastened. The wound was bandaged with sterile dressings. To create a low stress environment at the diseased femoral head, the adductor muscle was

relaxed when the diseased limb had an internal contracture before the operation.

These patients lay in the bed for rest after operations. They also performed muscle long adduction and some joint exercise activities using outreach and internal rotation motions of the hip in bed. Medicine was given periodically. Alcohol was dropped into the surrounding area of the screw track twice a day. Re-diagnosis was performed once every other week. The hinge joints were made sure to work well and lubricant oil was added if needed. The external supporting frame was removed after 2-3 months. The patients continued to reduce weight bearing for 3-4 months.

Complete follow-up data were obtained for 28 patients. Through radiology, many features were observed during the self-repairing of femoral head necrosis in children under a low stress environment. The preoperative and postoperative changes in thickness of epiphysis and degrees of hip flexion and extension were examined (Table 1).

Statistical analysis was performed by using the paired t. SPSS for Windows (version 19.0.1; SPSS, Inc., Chicago, IL, USA) was used to analyse the data. A P value of less than 0.05 was customarily considered significant.

#### **RESULTS**

Follow-up ranged from 2 to 7 years (mean 41 months). Comprehensive evaluations were made based on the patient's clinical complications and radiological changes and activity of hip. The supporting frame was used for an average of 10 weeks. There were five cases have complications, such as loosening, broken screw and infection, where a pressed groove and subluxation of a flat hip remained during follow-up. Five patients felt the hips uncomfortable because of the adhesion between the diseased hip and the scar. Seven patients were lame and recovered to normal activity after one year. Others had no complaints for uncomfortable. Partial stretching and flexion activities of the diseased hip were allowed with the use of the supporting frame. Patients could get down to walk with the help of a stick but without weight bearing.

The joint space broadened after using external fixator. The thickness of the epiphysis began to increase one month after the operation and was substantially increased two months after the operation. The thickness continued to increase after removal of the external fixed frame. The short-term and long-term follow-ups indicated that a low stress environment aided epiphysis thickness repair (Figure 2, 3, 4). The thickness of the epiphysis was obviously increased (P <0.01) and the femoral head became plump gradually (Table 1).

Through radiography, the femoral head high density shadow was large in Catterall stage II patients. The shadow occupied a big area in these patients, while the shadows of patients in Catterall stage III were of higher density and flatter. At stage IV, the shadows were flatter and of higher density, even showing the nucleus cleavage fracture status on the epiphyseal plate. The high density shadows of the epiphyseal nuclei shrank rapidly within 2-3 months after the low stress environment was established. Obvious repair was seen at the peripheries of the high density shadows (Figure 2, 4).

Under a low stress environment, the groove had a different degree of recovery two months after operation. Although radiography showed that the femoral head was flat and the acetabulum was poorly contained within the femoral head, the femoral head cartilage surface was still smooth (Figure 2, 3). Activities of the hip such as flexion and extension were significant improvement (P < 0.1) (Table 1).

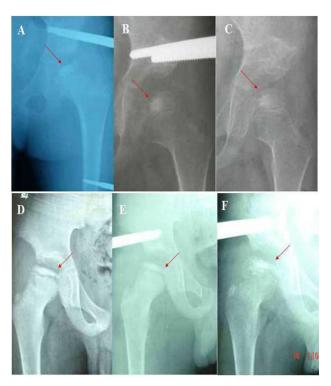


Figure 2: Left Perthes disease male patient at 6 Catterall III (A) The joint space broadened and the femoral head was flat. The high density shadows and groove were seen 1 day after surgery. (B) The high density shadows shrank and the height of epiphyseal increased. The groove was repaied obviously 1 month after surgery. (C) The high density shadows considerably shrank. The height of epiphyseal increased significantly. Well repair of the femoral head and groove was observed 3 months after surgery. Right Perthes disease male patient at 7 Catterall IV (D) The femoral head was flat and repair was seen at outer upper edge of the groove before surgery. (E) The joint gap broadened 1 day after surgery (F) The height of epiphyseal increased, and the femoral bone and groove repaired 1 month after surgery.

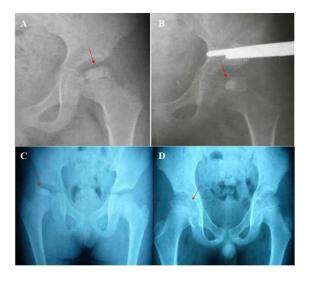


Figure 3: Left Perthes disease male patient at 6
Catterall III (A) The high density shadow is obvious and the flat femoral head and grooves were seen before surgery (B) The joint gap broadened, the high density shadow shrank, the height of epiphyseal increased and the groove began to repair 2 months after surgery. Right Perthes disease male patient at 5
Catterall IV (C) The femoral head was flat and the groove at the outer top of femoral head disappeared before surgery (D) The femoral head well repaired and the groove at outer top of femoral head disappeared.

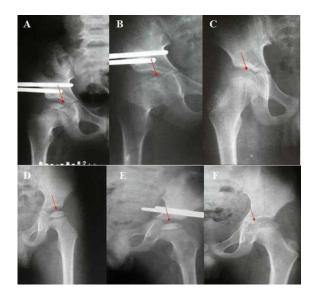


Figure 4: Right Perthes disease male patient at 8
Catterall III (A) The femoral head was flat 1 day after surgery (B) The joint gap widened and the height of epiphyseal increased 1 month postoperatively (C) The femoral head well repaired 1 year postoperatively.
Right Perthes disease male patient at 8 Catterall III
(D) The femoral head was flat and high density shadow were seen 1 day after surgery (E) The height of epiphyseal increased and high density shadow shrank 1 month after surgery (F) The femoral head well repaired 1 year postoperatively.

Table 1: Associated clinical outcome.

Patient No.	Sex	Age,	Unilateral or bilateral necrosis	Catterall stage	Thickness of epiphysis (mm)		Degrees of hip flexion (°)		Degree of hip extension (°)		Follow-
					Pre	Post	Pre	Post	Pre	Post	up, mo
1	Male	4	Unilateral	II	7.1	10.1	115	145	5	12	48
2	Male	6	Unilateral	III	7.3	9.4	111	135	3	9	46
3	Male	5	Unilateral	IV	6.8	8.7	100	120	0	8	38
4	Male	9	Unilateral	III	6.6	9.6	110	140	2	11	30
5	Male	10	Bilateral	IV	6.5/6.7	9.8/10.1	105/105	135/135	0/0	10/10	36
6	Male	5	Unilateral	II	7.3	10.2	117	145	5	13	28
7	Male	11	Unilateral	III	7.4	10.1	112	140	2	10	40
8	Male	8	Unilateral	III	7.2	10	110	135	3	11	37
9	Male	7	Bilateral	II	7.1/7.2	10.3/10.5	115/120	140/140	5/5	11/11	35
10	Male	12	Unilateral	IV	7	10	100	135	1	9	45
11	Male	4	Unilateral	III	7.2	10.2	112	140	4	10	38
12	Male	6	Unilateral	IV	6.8	8.3	95	115	0	8	33
13	Male	11	Unilateral	III	7.1	10.3	110	140	3	9	55
14	Female	9	Bilateral	II	7.5/7.3	10.3/10.1	115/115	145/140	5/5	13/12	70
15	Male	10	Unilateral	IV	7.1	9.8	100	140	0	9	28
16	Male	8	Unilateral	III	7.3	10	110	140	4	11	39
17	Male	7	Unilateral	IV	7.1	8.7	105	130	2	10	40
18	Male	4	Unilateral	III	7.4	10.4	110	140	2	10	27
19	Male	8	Unilateral	IV	7	9.6	105	140	1	11	44
20	Male	11	Unilateral	II	7.5	10.5	115	150	5	12	48
21	Female	9	Unilateral	IV	6.8	10.1	95	130	0	11	84
22	Male	5	Unilateral	III	7.3	8.2	105	130	2	9	28
23	Male	12	Unilateral	IV	6.9	9.9	95	130	0	10	40
24	Male	6	Unilateral	III	7	10.2	110	140	3	10	35
25	Male	9	Unilateral	II	7.6	10.5	115	145	5	11	38
26	Male	12	Bilateral	III	7.1/7.2	10.2/10.4	110/110	140/145	3/3	10/11	39
27	Male	8	Unilateral	II	7.3	10.6	120	150	5	10	29
28	Male	11	Unilateral	IV	6.7	9.5	90	130	0	9	51
					7.1063	9.8937	108.1875	137.6533	2.5938	10.3438	41.0357
					t=23.154	P <0.01*	t=15.465	P < 0.01*	t=18.670	P <0.01*	

<sup>\*</sup>Paired t test between the pre- and post-operative thickness of epiphysis, degrees of hip flexion and extension.

### **DISCUSSION**

Femoral head necrosis in children (Perthes disease) is a type of orthopedic disease. Incidence differs in different countries and is also dependent on the race. While, incidence rates vary considerably between countries, there is also significant variation within countries and even within regions. Pala Lameness and pain at the diseased site are the major characteristics of this disease. For some patients, there is no discomfort or pain at the hip during the early stages of the disease. Therefore, Perthes disease is easily misdiagnosed initially. Indeed, this was observed in the cohort of this study. The symptoms of the disease are not serious. The symptoms of some patients can only be relieved when rest. Radiography of some cases indicated serious femoral

head necrosis at Catterall stages III and IV. After incision of the joint capsule during operation, the appearance of the femoral head cartilage was flat and the surface of the articular cartilage was smooth. With the exception of the pressure mark on the outer top, no abrasions were observed on the acetabulum or femoral head. Therefore, there were no serious clinical symptoms. The disease appeared serious from radiography but moderate based on clinical symptoms.

Many researchers often focus on clinical symptoms when making assessments of efficacy. Therefore, the short-term acceptance rate for this disease has always been above 90% for conservative treatments, such as vessel pedicle tissue implantation, osteotomy and synovectomy. <sup>14,15</sup> However, in the follow-up appointments over the next

several years, some cases with "excellent" or "good" treatment effects showed big femoral heads, thick necks, coxa subluxation and even osteoarthritis on X-ray. After analysis of 48 patients (51 hips) with an average follow-up of 50.2 years, French scholar F. Lecuire<sup>3</sup> believed that the best indication of prognosis of the hip joint was the shape of the femoral head after the bone has matured. A normal spherical head had a good prognosis, while an irregular or very irregular femoral head had a poor prognosis. Based on the above long-term follow-up results, the prognosis of femoral head necrosis had a direct relationship with repair visualized via radiography.

Ischemia necrosis of the femoral head in children is a self-limiting disease. Necrotic femoral heads in children are continuously repaired during necrosis because they have a strong plasticity. However, the fresh bone cannot bear the pressure of the acetabulum because the newly restored bone has poor biomechanical properties. When a patient walking, the acetabulum continuously oppresses the femoral head while it is in a repairing process, resulting in fragmentation of the femoral head epiphyseal nucleus and the collapse and flattening of the femoral head epiphysis. 16,17 In addition, during the development of this disease, the femoral head appears big and the neck has been thick in the majority of cases. Due to the increase in the size of the femoral head, the containment of the femoral head by the acetabulum is poor and the acetabulum loses its coordination with the femoral head, leading to pressure and impact of the acetabulum on the outer top of the femoral head. This pressure and impact form a groove on the outer top of the femoral head. These two aspects, the pressure of the acetabulum in the process of repair of the femoral head and the impact of the acetabulum on the outer top of the femoral head, result in a flattening of the hip, a femoral head semi-dislocation deformity, and severe osteoarthritis.

In five cases of this study, at the postoperative follow-up, we still found an oppressed groove, no significant increase in epiphyseal thickness, and no significant reduction in the high density shadow of the epiphyseal nucleus.

This was primarily caused by a broken bone screw of the external supporting frame, a loosening of the external supporting frame due to infections in the screw tracks, or other reasons that prevented support of the coxa. There was still a high level of stress transmission in the femoral head, and the loose supporting frame narrowed the joint space (<0.5 cm), which could not be obtained in a low stress environment in femoral head. In addition, three of these cases were initially diagnosed as being Catterall stage IV. In this stage, the disease involves all of the femoral head and is accompanied by a diffusing metaphyseal reaction. Because the acetabulum could not completely contain the femoral head during the installation of the supporting frame, the contact surface of the joints was non-uniform. Load-bearing of the femoral head functioned at some sites with imbalanced pressure,

resulting in varying degrees of big heads, thick necks, and subluxation deformities of the femoral head.

In this group of 28 cases, a particular phenomenon in a low stress environment was observed: repair of the femoral head groove, increased epiphysis thickness and the disappearance of the high density shadow of the epiphyseal nucleus. From pathological mechanisms of the disease combined with this research, the loss of coordination between the acetabulum and the femoral head led to a physical impact of the acetabulum on the outer top of femoral head, forming a groove. The continuous oppression of the acetabulum on the femoral head in the process of repair resulted in fragmentation of the femoral head epiphyseal nucleus and collapse of the femoral head epiphysis. The low stress environment was imprecise in five cases. The pressed grooves and flattened hip subluxations found in these postoperative follow-ups prove this point.

From the perspective of radiography, two months after surgery in a low stress environment, the groove at the upper top of the femoral head was repaired to vary degrees, the thickness of epiphysis was obviously increased, the high density shadow of the epiphyseal nucleus rapidly shrank and repair was visibly obvious at the surrounding edge of the high density shadow. These phenomena showed that the low stress environment enhanced coordination between the acetabulum and the femoral head, avoiding or mitigating the impact and pressure of the acetabulum on the outer top of the femoral head. 18 In turn, it promoted reconstruction and remodeling of the newly restored trabecular bone and repair of the necrotic femoral head. This will prevent the formation of a big head and thick neck of the femoral head, coxa subluxation deformities, and late osteoarthritis significantly.

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Conflict of interest: None declared

Ethical approval: The study was approved by the institutional ethics committee

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