**Introduction**

Conventionally, treatment of Perthes disease has been roughly divided into conservative and surgical approaches. Despite the efforts of many clinicians involved in the treatment of this disease, repair of the necrotic femoral head in Perthes patients still often requires 2-3 years and the outcomes of treatment are affected by factors such as age and the extent of necrosis. It has been considered difficult to modify the natural course of this disease. For patients over 9 years of age, surgical treatment has been recommended because of the poor prognosis of these patients following conservative treatment. In the past, however, the only approach available was prevention of femoral head deformity through reduction of the restriction of hip range of motion and lateral hip subluxation in early stages of the disease and suppressing the decrease in lateral pillar height. No active treatment method has been recognized as being useful for shortening the treatment period. In 1993, we began to apply a combination of brace treatment and near infrared irradiation therapy (NIIT) to patients with this disease. We previously reported that patients having received this combined therapy showed early lateral pillar formation (through ossification of the lateral femoral head) at the stage of the disease previously known to often show markedly reduced mechanical strength of the femoral head nucleus and severe collapse, and that these patients require 2-3 years and the outcomes of treatment are affected by factors such as age and the extent of necrosis. It has been considered difficult to modify the natural course of this disease. For patients over 9 years of age, surgical treatment has been recommended because of the poor prognosis of these patients following conservative treatment. In the past, however, the only approach available was prevention of femoral head deformity through reducing the restriction of hip range of motion and lateral hip subluxation in early stages of the disease and suppressing the decrease in lateral pillar height. No active treatment method has been recognized as being useful for shortening the treatment period. In 1993, we began to apply a combination of brace treatment (requiring hospitalization) and near infrared irradiation therapy (NIIT) to patients with this disease. We previously reported that patients having received this combined therapy showed early lateral pillar formation (through ossification of the lateral femoral head) at the stage of the disease previously known to often show markedly reduced mechanical strength of the femoral head nucleus and severe collapse, and that these patients responding poorly to near infrared irradiation therapy.

**Key Words:** Perthes disease, Near infrared irradiation therapy, Femoral head collapse, Lateral pillar
remained free of marked collapse and their treatment period tended to be shortened.\(^4,5\) (Fig. 2-a,b,c,d,e). Of the 23 patients who began to receive this combined therapy, poor responders who developed femoral head collapse were reviewed. With emphasis on 2 cases (No.15 and 16) who were rated as poor according to Mose’s criteria because of femoral head collapse among the 16 patients who began to receive this therapy before early fragmentation phase, we reviewed the techniques for applying NIIT for Perthes disease.

**Fig. 1:** A 5-year-old boy with right Perthes disease, a typical non-irradiation therapy case. (a): The sclerosis stage is seen on the X-ray findings at the first examination, which is maintained at 5 months. (b),(c): One year after the start of uncombined brace treatment, the entire femoral head was still depicted as a low signal area on T2-weighted MRI, and necrosis affected the entire femoral head, with no sign of ossification. (d): Two years after the start of treatment, the femoral head had has flattened and prolapsed from the acetabulum, resulting in shortening of the femoral neck.
Subjects and Methods

The subjects of this study were 23 patients who had received combined brace and near infrared irradiation therapy. The duration of follow up was 1 year or more. There were 22 boys and 1 girl, with ages ranging from 5 to 10 years (mean: 7 years). The disease was bilateral in 2 cases.

Brace treatment was combined with the application of NIIT. Weight bearing was prohibited until

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**Fig. 2:** A 6-year-old boy with right Perthes disease. (a): On first examination, the sclerosis stage is seen on X-ray imaging. (b): As NIIT was initiated, rapid ossification of the lateral portion of the epiphyseal nucleus took place, the fragmentation stage was attained at 3 months after the initiation of therapy, and the lateral pillar was formed. (c): Final X-ray imaging at 9 years of age shows that the deformity of femoral head nucleus was slight. (d) and (e): At 3 months after the initiation of irradiation therapy, ossification of the medial and lateral portions femoral head nucleus was confirmed with MRI T2 weighted imaging.
repair of the weight-bearing femoral head was confirmed by MRI (for 10 months on average). The mean hospitalization period was one year. While hospitalized, the patients attended school within the Shinano Handicapped Children’s Hospital complex.

The instrument used was the Super Liser (SL) HA-550 delivering linear polarized infrared light energy (Tokyo Iken Ltd., Japan). The sites of irradiation were 2 sites on the anterior aspect of the affected hip joint, and 4 sites on the II and IV lumbar paravertebral mus-

cles on both sides to achieve irradiation of the region around the lumbar sympathetic ganglia. The methods and conditions of irradiation were as follows: with the use of the B type lens unit, continuous irradiation was performed with an output of 1800 mW once daily, 5 days per week, 3 minutes per site, 18 minutes in total.

The parameters used with the SL were as follows. Energy density per site with an output power of 1.8 W and incident power density of 2.3 W/cm² was 413 J/cm²/day and 2,063 J/cm²/week. The energy density delivered over the 6 sites was 2,475 J/cm²/day and 12,376 J/cm²/week. Preconditions were as follows. The lens used was the B unit, 100% (1.8 W) continuous. The spot diameter was 10 mm. Irradiation time per site was 3 minutes, once/day and 5 times/week. The number of the sites irradiated was 6. 4, 5)

In patients who experienced the sensation of intense heat during contact irradiation, heat sensation was alleviated by reducing the output to 70% and conducting a 50% duty cycle irradiation (on for 1 second, off for 1 second). The duration of irradiation therapy was 8 months to 1 yr and 5 months, 12 months on average. The duration of follow up was 2 yr and 6 months to 15 yr and 2 months, 7 yr and 6 months on average. For brace treatment, after relief of weight bearing by traction of the lower extremities for 1 month, a hip abduction flexion brace (bilateral abduction of the hip joint of 30° flexion 30°) was used. Weight bearing was forbidden until the MRI T2-enhanced image of the weight bearing portion of the femoral head was converted from a low to a high signal area.

The content of treatment was explained to the children and their parents, and NIIT was performed in conjunction with in-hospital brace treatment only on those patients who consented to the combination treatment.

### Results

Among the 23 patients who underwent this combination therapy, 5 were rated as poor according to Mose’s criteria because of femoral head deformity seen on the final X-ray. Among the 16 patients (No. 1-16) who began to receive treatment before the early fragmentation stage free of femoral head lateral pillar collapse, 2 were rated as poor but total femoral head necrosis was not seen in any case.

**Table:** Final X-rays.

Among the 23 patients who had received this combination therapy, 5 were rated as poor according to Mose’s criteria because of femoral head deformity seen on the final X-ray. Among the 16 patients (No. 1-16) who began to receive treatment before the early fragmentation phase free of femoral head lateral pillar collapse, 2 were rated as poor but total femoral head necrosis was not seen in any case.

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AHI: Acetabular head index
ATD: Articulo-trochanteric distance

No. 1–16: Patients started treatment before the early fragmentation stage
No. 17–23: Patients started treatment after the early fragmentation stage
**Fig. 3**: Case 1: An 8-year-old boy with bilateral Perthes disease. (a): On first examination X-rays shows the early fragmentation stage. (b) and (c): Five months after the start of treatment, this patient was admitted to another hospital for one month to be treated for another disease. Thus, our treatment was suspended. At 6 months, collapse had worsened. (d) and (e): MRI (T2-weighted) findings revealed high signal areas on the medial and lateral sides of the femoral head nucleus at 3 months. (f) and (g): The high signal areas continued to expand up to 4 months but a low signal area began to expand at 6 months due to collapse. (h) and (i): Compared with the X-ray findings at 9 months, on the basis of the final X-ray taken at age 16, the response of this case was rated as “poor” according to Mose’s criteria. (j): The disease first developed on the left side. This patient had received brace treatment on the left side at another hospital.
degree of femoral head prolapse from the acetabulum, showed acetabular covering of the femoral head to be evidently better in patients who had begun treatment before the early fragmentation stage (p<0.005) (Table). Among the 16 patients who began treatment before the early fragmentation phase, we hereafter present 4 case histories, 2 rated as poor according to Mose’s criteria because of femoral head collapse and 2 (No.15 and 16) who developed mild femoral head collapse during the course of treatment.

**Case 1: 8 year old boy, bilateral Perthes disease**

On first examination, X-ray images showed the sclerotic stage of the femoral head. According to our initial treatment approach, patients after one month of traction in bed were permitted to walk with a Batchelor type brace and crutches. The decrease in femoral head lateral pillar height was small at 4 months after the start of treatment, but no alleviation of lateral subluxation
Fig. 5: Case 3, a 5-year-old boy with right Perthes disease. (a): The X-ray findings on the first examination show the sclerosis stage. (b): An increase in lateral pillar height was noted at 3 months after the start of treatment, and the patient appeared to be following a favorable course. Later, this patient developed measles, and the resultant fever necessitated suspension of the treatment for 2 weeks. (c): At 5 months, collapse developed at the femoral head nucleus, accompanied by a decrease in lateral pillar height. (d): MRI (T2-weighted) findings at the first examination. (e): MR T2-weighted imaging reveals high signal areas on the medial and lateral sides of the femoral head nucleus at 3 months after the start of treatment, suggesting a favorable course of treatment. (f): At 5 months, the femoral head had flattened slightly due to collapse, but the low signal areas had not expanded. (g) and (h): At age 8, the response of this case was rated as “fair” according to Mose’s criteria on the basis of the last X-ray.
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(a) First consultation  (b)  
(c) 2 months  (d) 

(e) First consultation MRI T2-weighted image  (f)  
(g) 2 months  (h) 

(i) 2 months  (j)  

(k)  
(l)
Fig. 6: Case 4, a 5-year-old boy with right Perthes disease. (a) and (b): On first examination X-rays show the sclerosis stage. (c) and (d): An increase in lateral pillar height was noted at 2 months after the start of treatment, suggesting a favorable course of treatment. (e),(f),(g) and (h): MRI (T2-weighted) also revealed high signal areas on the medial and lateral sides of the femoral head nucleus, indicating a favorable course of treatment. (i) and (j): During the patient’s visit at 3 months, the lateral pillar was slightly shorter than the height recorded one month before, and the high signal areas on the medial and lateral sides of femoral head nucleus had become low signal areas (k) and (l). We then checked the output from the near infrared irradiation device and found that it had decreased to 1/3 of the original output as of 2 months after the start of treatment. It seems that for 43 days after discharge from our center, the patient continued near infrared irradiation therapy at an output level lower than appropriate. (m): At 6 months after the start of treatment, the femoral head nucleus had flattened slightly. (n): At 7 months, the change peaked. (o) and (p): MRI (T2-weighted) revealed high signal areas on the medial and lateral sides of femoral head nucleus at 7 months after the start of treatment. (q) and (r): On the basis of the final X-ray taken 1 year 2 months after the start of treatment, the response of this case was rated as “good” according to Mose’s criteria.
Case 2: 6 year old boy, right Perthes disease

On first examination, X-ray showed the sclerotic stage of the femoral head. According to our initial treatment protocol, after one month of traction in bed patients were permitted to walk with a Batchelor type brace and crutches. There was no decrease in femoral head lateral pillar height until 6 months after the start of treatment, and the patient followed a favorable course until that time. At 7 months, however, collapse appeared, probably due to weight bearing, and a fracture line perpendicular to the femoral head nucleus and flattening of the femoral head nucleus were noted. On the basis of the final X-ray at age 15, the response of this case was rated as “poor” according to Mose’s criteria (Fig.3-h,i). The disease first developed on the left side. This patient had received brace treatment at another hospital. Femoral head deformity similar to that on the right side was noted on the left side (Fig.3-j).

Case 3: 5 year old boy, right Perthes disease

On first examination, X-ray showed the sclerotic stage of the femoral head. An increase in lateral pillar height was noted at 3 months after the start of treatment, and the patient appeared to be following a favorable course. Later, this patient developed measles, and flattening of the femoral head nucleus was noted. On the basis of the final X-ray taken at age 16, the response of this case was rated as “poor” according to Mose’s criteria (Fig.3-a,b,c). The dis- ease first developed on the left side. This patient had received brace treatment at another hospital. Femoral head deformity similar to that on the right side was noted on the left side (Fig.3-j).

Case 4: 5 year old boy, right Perthes disease

On first examination, X-ray showed the sclerotic stage of the femoral head. An increase in lateral pillar height was noted at 2 months after the start of treatment, suggesting a favorable course of treatment (Fig.6-a,b,c,d). MRI (T2-weighted) also revealed high signal areas on the medial and lateral sides of the femoral head nucleus, indicating a favorable course of treatment (Fig.6-e,f,g,h). During the patient’s visit at 3 months, the lateral pillar was slightly shorter than the height recorded one month before, and the high signal areas on the medial and lateral sides of the femoral head nucleus had become low signal areas (Fig.6-i,j,k,l). This patient had been receiving outpatient treatment (brace treatment + near infrared irradiation therapy) at a local clinic due to living far away from our hospital. We explored the cause of the poor response in this case and learned from the patient’s guardian that the patient had not felt any heat sensation even after contact NIIT. We then checked the output from the NIIT device and found that it had decreased to one-third of the original output as of 2 months after the start of treatment. This patient had stayed in our center during the first month of treatment, receiving our combination therapy of mechanical traction and NIIT. It seems that for 43 days after discharge from our center, the patient continued NIIT in the other institution at an output level lower than appropriate. At 6 months after the start of treatment, the femoral head nucleus had flattened slightly. At 7 months, the change peaked (Fig.6-m,n,o,p). On the basis of the final X-ray taken 14 months after the start of treatment, the response of this case was rated as “good” according to Mose’s criteria (Fig.6-q,r).

Discussion

Combined therapy with brace and NIIT was applied in 23 cases of Perthes disease. Those responding poorly to this protocol (showing femoral head deformity on last X-ray) were common among cases in which the start of treatment was late (after the early fragmenta- tion phase). Total necrosis of the femoral head was...
seen in 3 (43%) of the 7 cases rated as poor responders. Femoral head deformity was severe in these cases. Among the 16 cases in whom treatment was started earlier (before early the fragmentation stage, i.e., in the absence of collapse of the femoral head lateral pillar), femoral head total necrosis was absent, and the outcome was favorable. According to the conventional view, the extent of femoral head necrosis is determined at the time when Perthes disease develops, and it is unlikely to vary regardless of the treatment method applied. 2) Our review of the results of the present study, however, suggests that the extent of femoral head necrosis is not a certainty at the onset of this disease. With conventional treatment approaches for Perthes disease, ossification of the lateral pillar is unsatisfactory and the lateral pillar remains mechanically fragile, possibly leading to a vicious circle of collapse (due to external forces such as weight bearing, muscular force, et cetera) and remission. As a result of this vicious circle, blood flow is likely to stop again after a temporary resumption, resulting in the onset of total necrosis. The favorable outcome seen in patients having received NIIT may be explained as follows. Improved blood flow due to the application of deep-penetrating near infrared energy stimulates early ossification at the lateral pillar, allowing resumption of blood flow without the onset of collapse. The affected area is probably then repaired, thereby avoiding total necrosis.

The poor outcome in Case 1 may be attributable to the influence of early resumption of weight bearing. Other factors possibly contributing to the poor outcome in this case are lack of alleviation of lateral subluxation of the femoral head and suspension of treatment for one month during the period of bone maturation, that outcomes were poor in cases having lateral subluxation and those with less than 50% lateral pillar height, whereas outcomes were better in patients developing the disease at or before 6 years of age.

After the poor outcome in Case 2, we modified our treatment protocol and adopted the MRI finding of a high signal area on the weight-bearing lateral side of femoral had as an indicator. With this treatment modification, weight bearing was prohibited until an evident sign of repair appeared, and patients were instructed to wear appliances and to use a wheelchair when moving. After Cases 1 and 2, none of our other patients were rated as “poor” according to Mose’s criteria.

Treatment was suspended in 2 cases. The duration of treatment suspension was 1 month in one case (Case 1) and 2 weeks in the other (Case 3). There were no other cases requiring treatment suspension for 7 days or more. Femoral head collapse occurred at 5-6 months after the start of treatment. Care in ensuring the correct irradiation parameters and adjustment of the frequency of irradiation, restriction of weight bearing and use of braces are essential for the first 7 months of treatment.

Analysis of the poor responders to this combined therapy revealed the ideal frequency of near infrared irradiation application and the timing of femoral head collapse development. These findings allowed us to modify our treatment protocol to achieve better outcomes, including shortening of the treatment period.

There is no established means of treating Perthes disease. Our approach (the combination of brace and NIIT) was shown in the present study to potentially alleviate femoral head necrosis in children with Perthes disease. This therapy is a promising approach to realizing the long-standing dreams (prevention of femoral head deformation without surgical treatment and shortening of the treatment period) of those managing children with Perthes disease.

Conclusions

1) Of the 16 cases having received a combination of brace treatment and NIIT since the early stage of Perthes disease, 4 developed femoral head collapse of varying degrees during treatment and 2 of these 4 were rated as poor according to Mose’s criteria.
2) Collapse occurred 5-6 months after the start of treatment. In the 2 cases rated as poor according to Mose’s criteria, it seemed that weight-bearing during a one-month suspension of treatment had also affected the onset of collapse.
3) To improve the outcome of near infrared irradiation therapy, it seems desirable to continue daily application without interposing a one-week or longer interval, and it is essential to ensure appropriate irradiation parameters and adjust the frequency of near infrared irradiation application, restrict weight bearing and use the therapeutic systems carefully during the first 7 months of treatment.
4) The present study allowed us to identify the optimal timing, frequency and conditions of near infrared irradiation application in patients with Perthes disease.
References


